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DECEMBER 1976
EDITION

Requirements For Soldered Electrical Connections

NASA
National Aeronautics and Space Administration

PREFACE

Date: December 1976

In order to maintain the high standards of the NASA soldering programs, this publication:

Prescribes NASA's requirements for hand and machine soldering for reliable electrical connections.

Describes and incorporates basic considerations necessary to ensure reliable soldered connections. Appendix C provides design guidelines to avoid solder cracking and solder-copper separation problems.

Establishes the supplier's responsibility to train and certify personnel.

Provides for supplier documentation of those fabrication and inspection procedures to be used for NASA work, including supplier innovations and changes in technology.

Provides expanded and improved visual workmanship standards in Appendix B.

APPLICABILITY

NASA Installations shall:

Invoke the provisions of this publication in procurements involving solder connections for aircraft, spacecraft, launch vehicles, mission essential support equipment, and elements thereof as appropriate to design or project needs. Appendices A and B are requirements of this publication. Appendix C, which discusses cracking problems, is provided for information and general guidance.

Amend, when timely and within cost constraints, existing contracts to invoke the requirements of this publication.

Utilize the provisions of this publication for in-house soldering operations and, as necessary, for training and certification of in-house personnel.

Assure that NASA contractors invoke the requirements of this publication in their subcontracts and purchase orders.

Furnish copies of this publication in the quantities required to NASA contractors, subcontractors and subtier suppliers.

Questions concerning application of this publication to specific procurements shall be referred to the procuring NASA installation or its designated representative.

Copies of this publication are available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

CANCELLATION

NHB 5300.4(3A), May 1968 Edition.

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Director
Program Assurance

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ORGANIZATION OF THE R&QA MANUAL

OVERALL COVERAGE

The Reliability and Quality Assurance Manual—referred to as the "R&QA Manual"—is the overall generic title which identifies all NASA R&QA management publications published under the basic R&QA subject classification code. The publications are grouped by major subject breakdown and further divided into specific categories identified as Parts. These Parts (not a complete R&QA Manual) are published as individual R&QA publications.

The following list shows the grouping and R&QA publications:

Title

Volume 1 - General Provisions

Title	Number
Reliability Program Provisions for Aeronautical and Space System Contractors	NHB 5300.4(1A) (April 1, 1970)
Quality Program Provisions for Aeronautical and Space System Contractors	NHB 5300.4(1B) (April 1969)
Inspection System Provisions for Aeronautical and Space System Materials, Parts, Components and Services	NHB 5300.4(1C) (July 1971)
Safety, Reliability, Maintainability & Quality Provisions for the Space Shuttle Program	NHB 5300.4(1D-1) (August 1974)

Volume 2 - Government Agency Provisions

Management of Government Quality Assurance Functions for Supplier Operations	NHB 5330.7 (April 1966)
Quality Assurance Provisions for Government Agencies	NHB 5300.4(2B) (Nov. 1971)

Volume 3 - Standards

Requirements for Soldered Electrical Connections	NHB 5300.4(3A-1) (December 1976)
Line Certification Requirements for Microcircuits	NHB 5300.4(3C) (May 1971)
Test Methods and Procedures for Microcircuit Line Certification	NHB 5300.4(3D) (May 1971)

	Number
Radiographic Inspection for Microcircuits	NHB 5300.4(3E) (Oct. 1971)
Qualified Products Lists Requirements for Microcircuits	NHB 5300.4(3F) (June 1972)

DOCUMENT REFERENCING

Each R&QA Manual Part is assigned its own identification number within the basic classification code. The numeric-alpha suffix within a parenthesis identifies the grouping of the publication, that is, the volume and part, such as NHB 5300.4(3A): this number indicates that this is the first "Standards" (Volume 3) publication to be issued.

When a part is revised, the suffix identification will be changed to indicate the revision number, such as NHB 5300.4(3A-1).

In referencing or requesting any R&QA publication, the complete specific NHB number must be used.

PARAGRAPH REFERENCING

1. **Within the R&QA Manual.** The following shows the paragraph numbering system applicable to all R&QA publications.

   3 A 3 01 1a(1)(a)

   Volume 3

   Part

   Chapter 3

   Paragraph 301

   Subparagraphs

   This system provides for referencing any R&QA publication requirement (paragraph) in any other R&QA publication without the need for identifying the NHB number, title, the volume number, or part. However, when referencing a complete Part within another R&QA publication, the specific NHB number must be used.

2. **In Other NASA Documents.** When it is necessary to reference an R&QA publication requirement (paragraph) in any other NASA document, the specific NHB number and paragraph number must be used together as follows: "NHB 5300.4(3A-1), par. 3A301-1a(1)(a)," or "paragraph 3A301-2b of NHB 5300.4(3A-1)."

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CHAPTER 1: BASIC PRINCIPLES

3A100 APPLICABILITY AND SCOPE

1. This publication is applicable to NASA in-house programs involving solder connections for aircraft, spacecraft, launch vehicles, mission essential support equipment and elements thereof and where invoked contractually in procurements.
2. This publication sets forth hand and machine soldering requirements for reliable electrical connections. The prime consideration is the physical integrity of solder connections.
3. Special requirements may exist which are not covered by or are not in conformance with the requirements of this publication. *Design documentation shall contain the detail for such requirements, and they will take precedence over conflicting portions of this publication when they have been approved in writing by the procuring NASA installation.*

3A101 PRINCIPLES OF RELIABLE SOLDERED CONNECTIONS

1. Reliable soldered connections result from proper design, control of tools, materials, and work environments, and careful workmanship.
2. The basic design concepts to ensure reliable connections and to prevent solder joint cracking are:
   a. Stress relief should be inherent in the design to avoid detrimental thermal and mechanical stresses on the solder connections. Appendix C discusses problems of solder cracking and solder-copper separation involving printed wiring boards.
   b. Where adequate stress relief is not possible, a method of solder joint reinforcement is necessary.
   c. Materials selection should provide minimal thermal expansion coefficient mismatch at the constraint points of the part mounting configuration.
   d. The design shall permit ready inspection of soldered connections.

3A102 GENERAL

1. NASA quality assurance personnel will advise and assist contractors, suppliers, NASA personnel, and delegated agencies in the proper and effective implementation of the provisions of this publication.
2. When related requirements or changes in requirements are specified, NASA quality assurance personnel will ensure that the Government agency dele-

gated to inspect at the supplier's site of fabrication has received full instructions so that the work will be inspected to the actual contract requirements.

3. Unless parts are manufactured specifically to comply with contracts or subcontracts citing this publication, internal connections of parts (as parts are defined in Appendix A) are not subject to the requirements of this publication. The supplier should assure himself that parts have suitable internal solder connections which will not unsolder or deteriorate when external connections are made.

4. When the supplier intends to use soldering processes, materials or connections not covered by this publication, the supplier shall document the details of fabrication and inspection, including acceptance and rejection criteria, and provide appropriate test data. Such documentation shall be approved by the procuring NASA installation prior to use.

3A103 RELATED DOCUMENTS

1. **Applicable Specifications.** Copies of the following applicable specifications required in connection with a specific procurement may be obtained from the procuring NASA installation or as directed by the contracting officer:

   Federal Specification QQ-S-571-E "Solder, Tin Alloy; Lead Tin Alloy; and Lead Alloy".

   Military Specification MIL-F-14256D "Flux, Soldering, Liquid (Rosin Base)".

   Federal Specification O-T-620 "Trichloroethane-1,1,1, Technical, Inhibited".

   Unless otherwise specified, the issue in effect on the date of invitation for bids or request for proposal shall apply.

2. **Reference Publication.** The fourth edition, NASA SP-5002 "Soldering Electrical Connections," contains many detailed suggestions and techniques on how to satisfy the requirements of this publication. SP-5002 is available for purchase from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. NASA personnel should order copies through their installation technical library.

3A104 DEVIATION AND WAIVER REQUESTS

1. This publication requires:

   a. Written approval of the cognizant NASA contracting officer or his designated NASA representative, for technical changes, deviations, or waivers initiated by the supplier.

   b. All deviation and waiver requests shall be supported by objective evidence and data substantiating that quality will not be compromised.

2. The prime contractor is responsible for assuring that any departures from this publication are evaluated, coordinated with, and submitted to the procuring NASA installation for approval.

3A105 REWORK

Rework is permissible unless excluded by other provisions of the contract. All rework shall meet the requirements of this publication. Rework is not repair. Repair shall be made only in compliance with applicable contractual requirements.

3A106 DEFINITIONS

For the purposes of this publication, the definitions in Appendix A shall apply.

CHAPTER 2: SUPPLIER SOLDERING PROGRAM

3A200 GENERAL

The supplier is responsible for maintaining a documented soldering program which meets the requirements of this publication for the types of solder connections utilized in the articles involved. Portions of this publication, including illustrations, and NASA SP-5002, may be abstracted for the supplier's program.

3A201 TRAINING AND CERTIFICATION

The supplier is responsible for:

1. Assuring that his electronics packaging design personnel are familiar with the requirements of this publication and other pertinent requirements of the contract.
2. Providing necessary training of his soldering and inspection personnel in connection design and soldering techniques, equipment and procedures pertinent to the areas of responsibility of each in performance of the contract or purchase order.
3. Ensuring that each individual who solders or inspects soldered connections is appropriately skilled in the types of connections involved in his assigned work.
4. Certifying each individual who solders or inspects soldering as being currently qualified to fulfill all requirements of this publication pertaining to the types of connections involved in his assigned work. Demonstration of proficiency is a prerequisite for such certification. Records or evidence of certification status shall be maintained in the work area.
5. Maintaining appropriate records of training and of certification criteria.

3A202 MAINTENANCE OF CERTIFIED STATUS

1. The procuring NASA installation or its designated representative, or the supplier's instructor, may require supplier soldering personnel to demonstrate proficient workmanship on applicable hardware, or to be recertified.
2. The procuring NASA installation or its designated representative, or the supplier's instructor, may require supplier inspection personnel to demonstrate proficient inspection performance and knowledge on applicable hardware, or to be recertified.

3A203 RECERTIFICATION

1. Recertification shall be required when:
   a. Proficiency requirements herein are not met. The need for recertification shall be based on observation of the unsatisfactory quality of articles fabricated by a solderer or accepted by an inspector.
   b. New techniques have been developed which require different skills.
   c. Certificate holder changes employment.
   d. Interruption of a work period for more than 90 days.
2. Procedures for recertification shall include sufficient training or retraining to enable the candidate to demonstrate proficiency in fabricating or inspecting the types of solder connections involved in his assigned work. A proficiency demonstration shall be required of each candidate.

3A204 REVOCATION OF CERTIFIED STATUS

Certification shall be revoked for operators or inspectors when:

1. Certificate holder requires recertification according to paragraph 3A203 and fails to be recertified.
2. Certificate holder fails to meet visual acuity requirements of paragraph 3A205.
3. Certificate holder leaves employment.
4. Supplier training program fails to meet requirements as set forth herein or as set forth otherwise in the contract.

3A205 VISION REQUIREMENTS

1. Supplier is responsible for ensuring that all personnel who perform soldering or inspect soldered connections meet the following vision test requirements as prerequisite to training and to certification and recertification. The vision requirements may be met with corrected vision (personal eyeglasses). However, any correction necessary to meet vision requirements will be documented on the certificate. Where work is performed under a microscope, suitable verification of necessary visual acuity shall be made. The eye tests shall be administered by qualified personnel, using standard instruments and techniques. Results of the visual examinations shall be maintained and available for review.
2. The following are the minimum vision requirements:
   a. **Far vision.** Snellen Chart 20/50.
   b. **Near vision.** Jaeger 1 at 14 inches; or reduced Snellen 20/20 or equivalent.
   c. **Color vision.** Ability to distinguish red, green, blue, and yellow colors as prescribed in Dvorine Charts, Ishihara Plates, or AOD-HRR Tests.

A practical test, using color coded wires and/or color coded electrical parts as applicable, will be acceptable for color vision testing.

3A206 WORKMANSHIP STANDARDS

The supplier shall:

1. Utilize visual standards consisting of satisfactory work samples or visual aids which clearly illustrate the quality characteristics for all types of soldered connections applicable to the contract or purchase order.
2. Utilize applicable illustrations in this publication, supplemented as necessary, for visual standards. Standards of unacceptable condition may also be used for clarification or comparison.
3. For approved connections other than those illustrated herein, prepare appropriate work samples or visual aids.
4. Make applicable standards readily available to personnel involved and use these standards in the training program.

3A207 DOCUMENTATION

1. Documents required herein, except as required by paragraph 3A102-4, shall be submitted to the procuring NASA installation or its designated representative as required by the contract or purchase order. Applicable supplier soldering program documents, or portions thereof, accepted on other NASA contracts shall be included to avoid duplication of effort.
2. The supplier shall describe the training and certification program he proposes to satisfy the requirements herein for the types of solder connections he will make. This description shall include the following, as applicable:
   a. Qualification of Instructors
   b. Procedures for training, including who will be trained and for what purpose, i.e., fabricator, inspector, etc.
   c. Lessons Plan(s)
   d. Hours of instruction
   e. Procedures for certification and recertification
   f. Procedures for recording of training, recertification, method of identifying trained personnel
   g. Certification criteria
3. The supplier shall document the methods and procedures proposed to incorporate the requirements of this publication into the design, fabrication and inspection of solder connections involved in the contract or purchase order.

CHAPTER 3: FACILITIES, EQUIPMENT, AND MATERIALS

3A300 FACILITY CLEANLINESS

The supplier is responsible for maintaining soldering areas in a clean orderly condition. Smoking, eating, and drinking at the work stations shall not be permitted.

3A301 ENVIRONMENTAL CONDITIONS

1. The soldering area shall have a controlled environment which limits entry of contamination. This area shall be continuously controlled as follows:

   Temperature .... 75° ± 10°F

   Relative Humidity .... (Min. 25% / (Max. 60%

   Parts or equipment being processed that require more critical environmental conditions than the preceding shall have such requirements identified and specified in the design documentation. Such requirements will have precedence over the above general environments.

2. In field operations where required controlled conditions cannot be effectively achieved, special precautions shall be taken to maintain the required quality of solder connections.

3A302 LIGHTING REQUIREMENTS

Light intensity shall be a minimum of 100 foot-candles on the surface being soldered.

3A303 TOOL AND EQUIPMENT CONTROL

The supplier shall:

1. Select tools and equipment used in soldering, and in preparation thereto, for intended function.
2. Properly clean and maintain equipment and tools.
3. Document or reference, in the supplier's soldering program detailed operating procedures and maintenance schedules for tools and equipment requiring calibration or set-up.
4. Maintain records of tool calibration and verification.

3A304 HEAT SOURCES

1. **General.** The supplier shall:

   a. Choose a means of applying and controlling heat to the metals to be joined that is compatible with the size, shape, and thermal conductivity of the work pieces.

   b. Provide procedures for control of the cleanliness of the heat source to ensure uniform heat transfer and prevent contamination of the solder connection.

   c. Forbid use of soldering guns.

2. **Resistance-Type Soldering Electrodes.** The surfaces of electrodes shall be kept free of contamination and corrosion.

3. **Conduction-Type Irons.** Soldering irons shall be electrically grounded. Prior to and periodically during use, the tip shall be checked for:

   a. Proper insertion

   b. Tight attachment

   c. Cleanliness

   d. No oxidation scale between tip and heat element.

   e. Continuously tinned surface on the tip working surface to ensure proper heat transfer and to prevent transfer of impurities.

4. **Noncontact Heat Sources.** When heat is applied by a jet of hot gases or by radiant energy beams, the supplier shall set up, operate, and maintain the equipment by established, documented procedures.

CAUTION

HEAT SHALL NOT BE APPLIED TO A SOLDERED CONNECTION OR ADJACENT AREAS IN SUFFICIENT INTENSITY TO DEGRADE THE CONNECTION OR DAMAGE ADJACENT PARTS OR AREAS.

3A305 CONDUCTOR PREPARATION TOOLS

The supplier shall select and use conductor preparation tools as follows:

1. Select insulation strippers and lead bending tools which do not nick, ring, gouge, or scrape conductors or otherwise damage parts.

2. Select part lead cleaning tools which do not damage leads and parts and which do not cause contamination or hinder solder wetting.

3. Use the correct size of stripping tools or machines and maintain them in calibration. Calibration method, interval, and status shall be documented by the supplier.

4. Verify, periodically, insulation strippers and lead bending tools for proper operation.
5. Prohibit unauthorized, defective, or uncalibrated tools in the work area.

3A306 THERMAL SHUNTS

Thermal shunts (also called heat sinks or heat dissipator clamps) shall be used to absorb heat from part leads or wire where necessary to protect parts, insulating materials, and/or previously completed connections from damage during soldering operations. Care shall be taken in the selection, application and removal of thermal shunts to avoid damage to conductors, components, parts, insulation, or associated solder connections.

3A307 IN-PROCESS STORAGE AND HANDLING

1. The supplier is responsible for the development and implementation of requirements and procedures necessary to prevent damage and to control conditions that could degrade the reliability of parts and deliverable items. In particular, means shall be provided to prevent damage or contamination of printed wiring termination areas, terminals, connectors, wire ends, or part leads during handling and storage. Containers shall be compatible with materials stored.
2. When handling of bare metal surfaces which are to be soldered is unavoidable, clean lint-free gloves or finger cots shall be used. If metal surfaces are handled with a bare hand or otherwise become contaminated, they shall be immediately cleaned using a solvent specified in par. 3A311.
3. Containers for handling parts sensitive to static electric charges shall be labeled as such. The supplier shall store and handle such parts prior to installation with the leads shorted together and shall store them in conductive plastic bags or other suitable containers.

3A308 MATERIALS SELECTION

The supplier is responsible to ensure that materials selected to be soldered will readily accept solder and permit the desired degree of wetting and tinning.

3A309 SOLDER

Solder shall conform to Federal Specification QQ-S-571E. For general applications, hand soldered connections shall be made with type RMA or RA cored solder. For applications where adequate subsequent cleaning is not practicable, type R cored solder shall be used. Type S, form B or I may be used for solid solder (pots and baths). Composition shall be Sn60 or Sn63.

3A310 FLUX

1. **Types and Usage.** The supplier's process documentation shall describe the types of fluxes, where each is used, and necessary precautions. The use of water soluble and acid type fluxes are prohibited for hand soldering.

2. **Liquid Rosin Flux.** Liquid rosin flux shall conform to MIL-F-14256D, Type RMA, except that the copper mirror test (par. 3.5) is not required, the resistivity of water extract (par. 3.2.5) shall be at least 45,000 ohm-centimeters, and the chlorides/bromides test (par. 3.2.6) is not required. Liquid flux used with flux-cored solder shall be chemically compatible with the solder core flux and with the materials with which it will come in contact. The use of liquid rosin flux is restricted to the wicking-off procedure for rework of soldered connections, tinning operations, reflow soldering, and automatic machine soldering.

3A311 SOLVENTS

1. Solvents shall be nonconductive and noncorrosive, and shall not dissolve or degrade the quality of parts or materials. Solvents shall be properly labeled and maintained in a clean and uncontaminated condition. Those showing evidence of contamination or decomposition shall not be used.

CAUTION!

FLUX OR SOLVENTS SHALL NOT BE USED IN ANY MANNER WHICH WILL CARRY TO OR DEPOSIT RESIDUE ON CONTACT SURFACES SUCH AS THOSE IN SWITCHES, POTENTIOMETERS, OR CONNECTORS.

2. The following solvents are acceptable when properly used for cleaning before or after soldering:
   a. Ethyl alcohol, ACS grade, 99.5% or 95% by volume.
   b. Isopropyl alcohol, best commercial grade, 99% pure.
   c. Trichlorotrifluoroethane, clear, 99.8% pure.
   d. Any mixtures of the above.
   e. 1,1,1-Trichloroethane, Federal Specification O-T-620.
   f. Deionized water; however, care shall be used to ensure that proper drying is accomplished immediately after its use.

CAUTION!

SONIC OR ULTRASONIC VIBRATION SHALL NOT BE USED AS A METHOD FOR CLEANING ELECTRICAL OR ELECTRONIC PARTS OR ASSEMBLIES UNLESS IT HAS BEEN DEMONSTRATED THAT THE RELIABILITY OF THE PARTS OR ASSEMBLIES WILL NOT BE DEGRADED BY THE PROCESS TO BE USED.

3. Procedures for cleaning and flux removal shall be documented prior to use.

CHAPTER 4: PREPARATION FOR SOLDERING

3A400 PREPARATION OF CONDUCTORS

1. **Insulation Removal.** Stripping machines or hand tools used to remove conductor insulation shall be of the correct size and in current adjustment and/or calibration.

2. **Damage to Insulation.** After insulation removal, the remaining conductor insulation shall not exhibit any damage such as nicks, cuts, crushing, or charring. Conductors with damaged insulation shall not be used. Slight discoloration from thermal stripping is acceptable.

3. **Damage to Conductors.** After removal of the conductor insulation, the conductor shall not be nicked, cut, scraped, or otherwise damaged. Part leads and other conductors which have been reduced in cross-section area shall not be used. Damaged wires shall not be used.

4. **Wire Lay.** The lay of wire strands shall be restored as nearly as possible to the original lay if disturbed. Contact with bare fingers shall be avoided; however, if contact is made, the wire shall be cleaned with an approved solvent prior to further processing.

5. **Tinning of Conductors.** The portion of stranded or solid wires and part leads that will eventually become a part of the finished solder connection shall be tinned with hot tin-lead solder and cleaned prior to attachment. Hot solder tinning on part leads shall not extend closer than 0.020 inch to part bodies or end seals. Additional flux may be used. The flux shall be applied so that it does not flow under the insulation except for traces carried by solder wicking. Flux shall be removed using the cleaning solvent applied so that its flow under the conductor insulation is minimal by avoiding use of excessive solvent and positioning so that gravity keeps solvent from flowing under the insulation.

   a. Ultrasonic tinning is preferred and, if used, shall be employed with caution to prevent damage to parts.

   b. Gold plating on all conductive surfaces which become a part of the finished solder connection shall be removed by ultrasonic tinning, by one or more successive tinning operations (solder pot or iron), or by other processes demonstrated to have equivalent effectiveness.

   c. Solder baths or solder pots shall be analyzed on an established schedule based on usage to ensure that solder composition is not contaminated with copper in excess of 0.25 percent by weight or gold in excess of 0.2 percent, with the total of gold plus copper not to exceed 0.3 percent. Contamination with zinc, cadmium, aluminum or iron is to be carefully avoided. Schedules for analysis of solder pots and baths shall be included in the supplier's solder program documentation, and records of analyses shall be kept (see par. 3A207). When the solder produces a dull, frosty or granular appearance on the work, the bath shall be removed from use.

6. **Wicking.** Flow (wicking) of solder along the conductor is permitted but shall not make the presence of the conductor strands at the termination end of the insulation indistinguishable.

7. **Splices.** Conductors shall not be spliced.

3A401 PREPARATION OF TERMINALS AND SOLDER CUPS

Terminals and solder cups shall be examined and cleaned immediately prior to attachment of conductors. Terminals and solder cups shall not be modified to accommodate improper conductor sizes.

3A402 PREPARATION OF PRINTED WIRING BOARD TERMINATION AREAS

Termination areas shall be "tinned" with hot coated tin-lead solder or hot reflowed electro-deposited tin-lead prior to the mounting of parts. All other coatings and platings shall have been removed from the termination areas beforehand. Removal shall not damage the copper conductor or add permanent contaminants. Boards shall be cleaned before further processing. Solder shall not be applied to a termination area which has not had the gold plating removed. See Appendix C for a summary discussion of solder-circuitry separation problems.

CHAPTER 5: PARTS MOUNTING

3A500 GENERAL REQUIREMENTS

Parts, terminals and conductors shall be mounted and supported as prescribed herein. These requirements apply to assemblies designed to operate within temperature limits from minus 55°C to plus 100°C. More extreme temperatures or other unusual environmental applications will require special design measures to provide necessary environmental survival capability. Such measures shall be detailed on the appropriate hardware drawings and specifications. Design documentation shall prescribe which of alternative approaches is selected, as well as staking compounds and conformal coating requirements. They shall also detail any special mounting arrangements or design requirements not fully covered herein.

1. **Stress Relief.** Stress relief shall be incorporated wherever possible into all leads and conductors terminating in solder connections to provide freedom of movement of part leads or conductors between points of constraint. Freedom of movement shall be sufficient to prevent detrimental stresses to either the part or solder connection due to expansion or contraction caused by thermal variations or mechanical excursions. Excessive lead lengths or large loops between constraint points shall be avoided to prevent assembly and vibration damage or electronic performance problems. Leads shall not be temporarily constrained against spring-back force during soldering so that the joint is subject to residual stress. Some examples of stress relief are shown in Figures 5-2, 5-3, 5-4, 5-5, 5-8, and 5-9.

2. **Heavy or Irregularly Shaped Parts.** When the shape of the part is such that only point contact can be made with the mounting surface, or if the weight of the part exceeds 1/2 ounce (14 grams), additional support shall be provided to protect against shock, acceleration and vibration environments. Cementing or mechanical means may be used. The method used shall not produce stresses which could cause functional degradation or damage to the part or assembly. Design documentation shall show details of the method of support.

CAUTION!

WHEN STAKING (CEMENTING) PARTS WITH PLASTIC MATERIALS, CARE SHOULD BE EXERCISED TO AVOID NEGATING THE STRESS RELIEF DESIGNED INTO THE ASSEMBLY OR INTRODUCING ADDITIONAL STRESSES.

3. **Metal Cased Parts.** Metal cased parts mounted over printed conductors or which are in close proximity with other conductive materials, shall be separated by transparent insulation of suitable thickness. Insulation shall be accomplished so that part identification markings remain visible and legible.
4. **Heat Generating Parts.** Heat generating parts (generally one watt or more) should be thermally shunted by a method such as clamps or heat conductive staking to minimize the heat dissipation into the solder terminations.
5. **Glass Encased Parts.** Glass encased parts, such as diodes, thermistors or resistors, shall be encased in transparent resilient sleeving or coating material when epoxy material is used for staking, conformal coating, or encapsulating or where damage from other sources is likely. The epoxy material shall not be applied directly to glass.

CAUTION!

WHEN USING HEAT SHRINKABLE TUBING, EXTREME CARE SHOULD BE TAKEN TO PREVENT PART DAMAGE DUE TO EXCESSIVE HEAT OR SHRINKAGE OF THE TUBING.

6. **Coated Parts.** Parts shall be mounted so that the insulating coating applied by the manufacturer on the leads does not enter the mounting hole or soldered connection.
7. **Lead Bending and Cutting**
   a. During bending or cutting, part leads shall be supported on the body side to minimize axial stress and avoid damage to seals or internal bonds. The inside radius of bend shall not be less than the lead diameter or ribbon thickness. The distance from the bend to the end seal shall be approximately equal at each end of the part. The minimum distance from the part body or seal to the start of the bend in a part lead shall be two lead diameters for round leads and 0.020 inch for ribbon leads. The direction of the bend shall not cause the identification markings on the mounted part to be obscured. Where the lead is welded (as on a tantalum capacitor) the minimum distance is measured from the weld.
   b. All leads shall be tinned, formed, and trimmed prior to mounting the part. Unless soldered to a pad, unused leads shall be cut to an approximate length of two lead widths, but in no case less than 0.020 inch from the part body or lead seal. No more than half of the total number of leads on any one side of a part may be cut off. If the number of unused leads exceeds this proportion, some must be soldered to blind pads for part mounting strength.
8. **Hookup Wire.** Solid hookup wire shall be supported by a means other than the solder connections if wire length exceeds one inch. Distance between supports should not exceed one inch. Attachment to a surface by conformal coating or staking with resin is adequate support. A single wire shall not be used to connect more than two points.

9. **Splices.** Broken or damaged wires, part leads or printed wiring conductors shall not be spliced.

10. **Location.** Part bodies shall not be located over or in contact with soldered or welded terminations.

11. **Conformal Coating, Staking (cementing), and Encapsulating.** Conformal coatings, staking (cementing), and/or encapsulating should be used where required to provide necessary mechanical support and protection against contamination. Design documentation shall specify the types of materials and related procedures necessary to provide mechanical support.

> **CAUTION!**
>
> WHEN CONFORMAL COATING, STAKING (CEMENTING), OR ENCAPSULATING PARTS WITH PLASTIC MATERIALS, CARE SHOULD BE EXERCISED TO AVOID NEGATING THE STRESS RELIEF DESIGNED INTO THE ASSEMBLY OR INTRODUCING ADDITIONAL STRESSES. COATINGS AND STAKING COMPOUNDS SHALL NOT BE ALLOWED TO BRIDGE STRESS RELIEF LOOPS OR BENDS AT TERMINATIONS IN PART LEADS OR CONNECTING WIRES.

3A501 MOUNTING OF TERMINALS

1. Use of terminals shall be restricted generally to situations where parts are expected to be removed and replaced five times or more, or where there are other compelling design requirements.

2. Swage type terminals designated to have the terminal shoulder soldered to printed wiring shall be secured to the printed wiring board (PWB) by a roll swage. (See Figure 5-1A.)

3. Board designs calling for soldering of the swaged end of the terminal to printed wiring on single sided boards shall not be used except for compelling design reasons. (In such case a V-funnel swage shall be used.)

4. Terminals shall not be used as interfacial connections on PWB's.

5. Swage type terminals that are mounted in a plated-through hole (PTH) shall be secured to the PWB by an elliptical funnel swage to permit complete filling of the PTH with solder. (See Figure 5-1B.)

6. Swaging shall be accomplished so as not to damage the PWB.

7. All swaged solder connections shall be heat sinked during the component lead soldering operation. Also, care shall be exercised to assure that swaged solder connections are not mechanically stressed during part mounting operations.

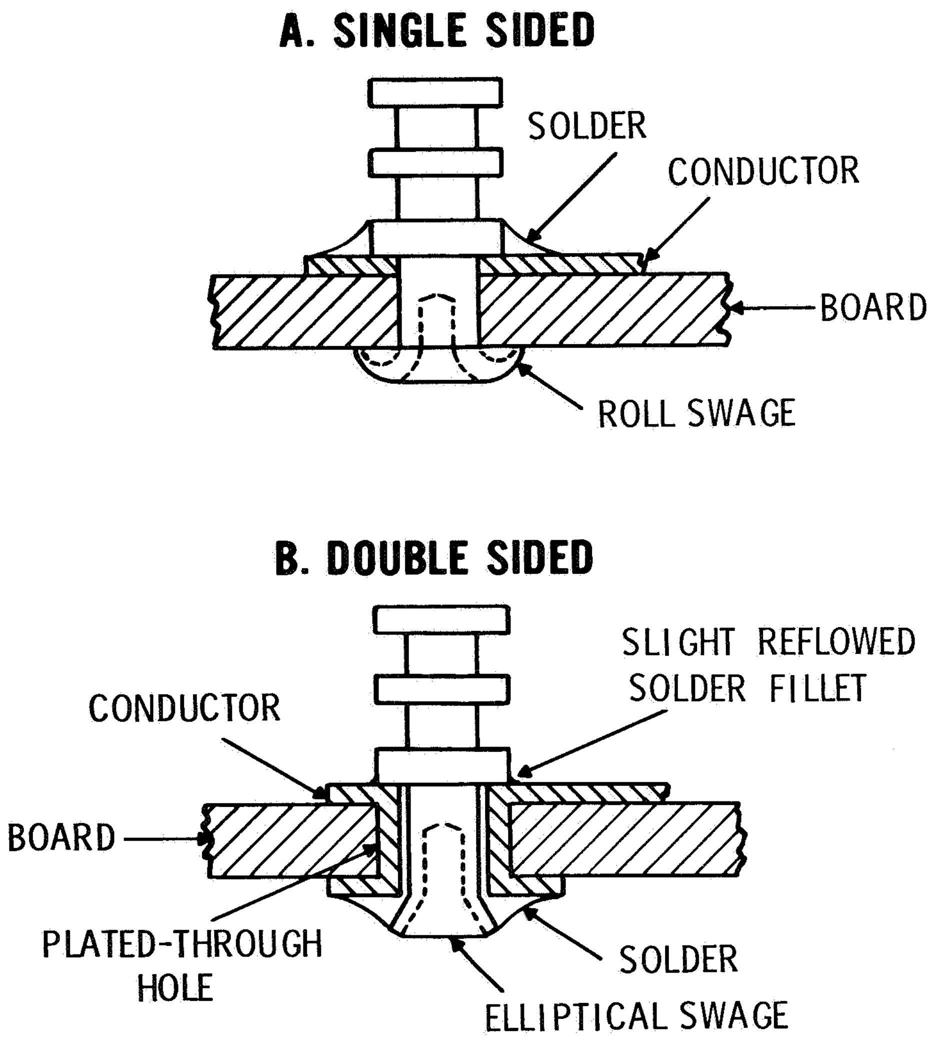
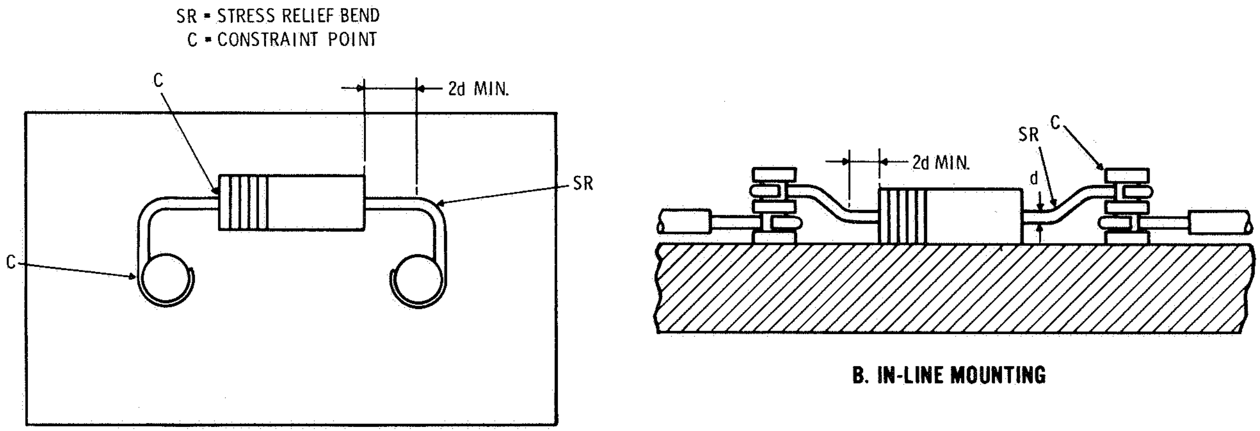


FIGURE 5-1
TYPES OF TERMINAL SWAGING

3A502 MOUNTING OF PARTS TO TERMINALS

1. **Parallel Mounting.** Parts shall be mounted parallel to and in contact with their mounting surface.
2. **Lead Lengths.** The length of leads between parts and terminals shall be approximately equal at both ends, except when special part shapes, such as flanges on top-hat diodes, require staggering.
3. **Stress Relief.** Each lead shall have provision for stress relief. (See Figure 5-2.)
4. **Wrapping and Routing.** Degree of wrap, routing, and connection to terminals are specified in Chapters 6 and 7.



A. OFFSET MOUNTING

B. IN-LINE MOUNTING

FIGURE 5-2

METHOD OF STRESS RELIEVING PARTS ATTACHED TO TERMINALS

3A503 MOUNTING OF PARTS TO PRINTED WIRING BOARDS

1. **Parallel Mounting.** Parts shall be mounted parallel to, and in contact with their mounting surface.
2. **Parts with Leads Terminating on Opposite Sides.** Stress relief shall be provided in the part lead between the part body and solder terminations. (See Figure 5-3.) The lead may be terminated by clinch, stud, or lap configuration.
3. **Parts with Leads Terminating on the Same Side.** Stress relief shall be provided by forming the part leads at a bend angle to the PWB of not more than 95° nor less than 45°. (See Figure 5-4.) Terminate using the lap termination of paragraph 3A504-4 and 5.
4. **Conductors Terminating on Both Sides.** Stress relief shall be provided in the part lead between the part body and solder terminations. When a solid hookup wire is used to interconnect solder terminations on opposite sides of a PWB, stress relief shall be provided in the wire between both terminations. (See Figure 5-5.) A PTH may be used in lieu of stress relief only if stress relief cannot be incorporated.

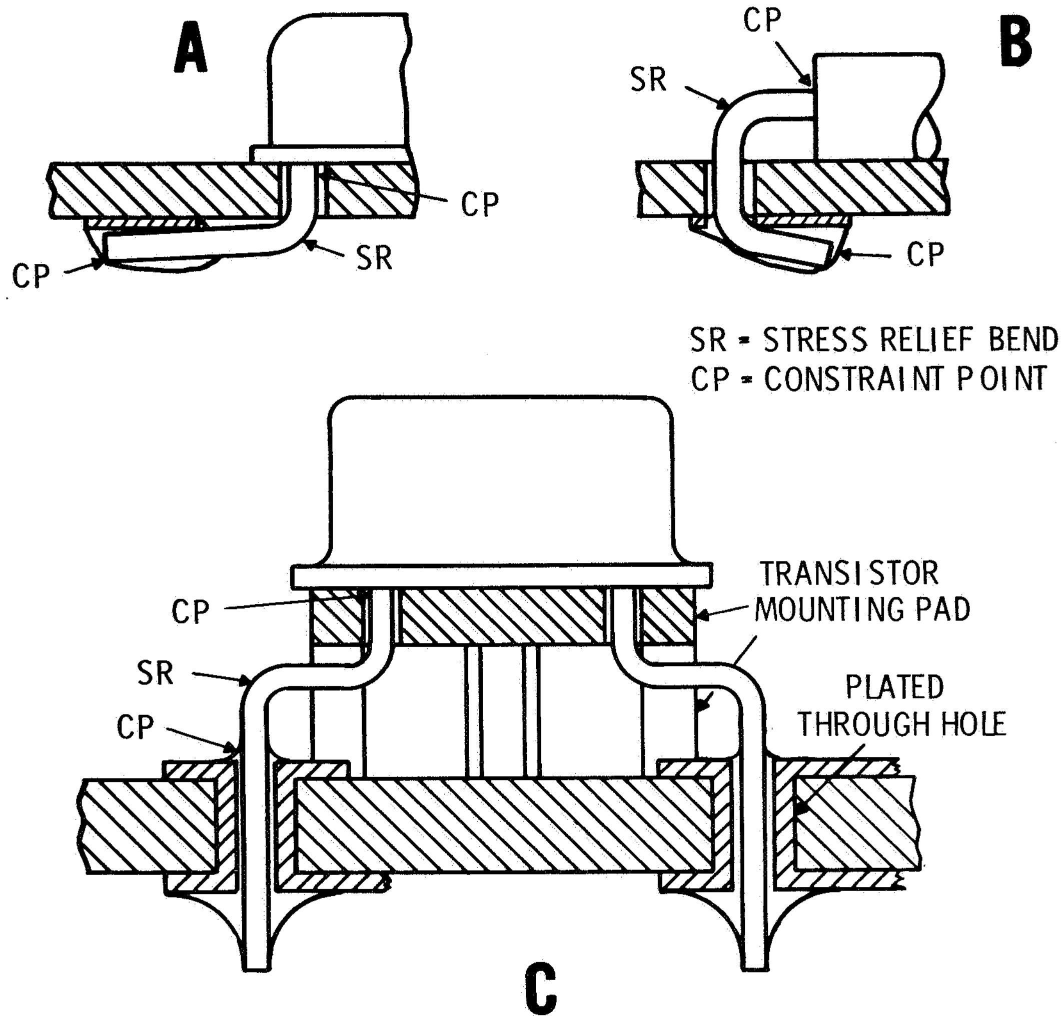


FIGURE 5-3

STRESS RELIEVED PART TERMINATIONS ON PRINTED WIRING

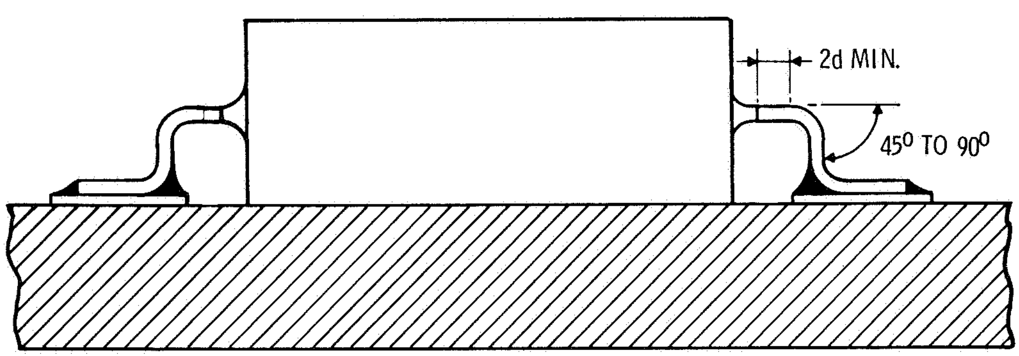


FIGURE 5-4

PART AND SOLDER TERMINATION ON SAME SIDE

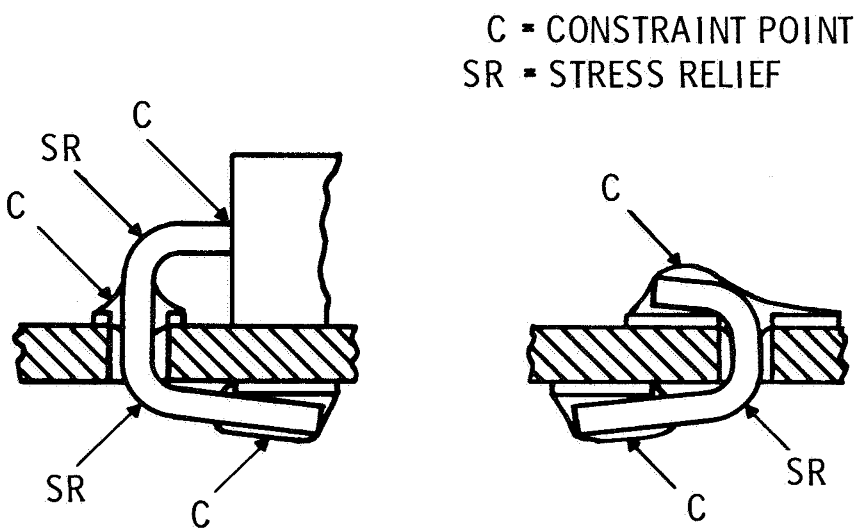


FIGURE 5-5
LEADS WITH SOLDER TERMINATION ON BOTH SIDES

3A504 LEAD TERMINATIONS, PRINTED WIRING BOARDS

All terminating surfaces shall be solder tinned prior to soldering. Solder terminations shall be visible for inspection after soldering. Part leads will be generally terminated to the PWB by lap, clinch, or stud terminations. Recommended terminations are shown throughout this Chapter. Generally, the pad should not exceed 4 times the minimum required solder pad area. (See Figure 5-11.)

1. **Lead Access Holes.** A separate hole shall be used for each lead extending through the PWB. The number of different hole sizes should be kept to a minimum.

   a. **Unsupported lead holes.** The diameter of an unsupported hole used for a clinch or stud termination should not exceed, by more than 0.008 inch, the nominal diameter of the part lead. (See Figure 5-11B and 5-6A.) The diameter of a hole used for a lap joint should not exceed 1.5 times the nominal lead diameter or width.

   b. **Plated-through holes (PTH's).** Whenever the part mounting configuration or lead diameter does not allow for stress relief, the solder connection shall be reinforced by a PTH and additional external solder. (See Figure 5-6B.) This provides joint reinforcement by increasing the solder shear area in the connection. PTH's shall not be used unaided as an interfacial electrical connection between conductor patterns on standard double-sided PWB's. However, this requirement does not apply to multilayer boards. A solid conductor, or a part lead shall be used to make the interfacial connection. Eyelets or tubelets shall not be used on PWB's. The finished diameter of PTH's should provide from 0.012 to 0.025 inch clearance between the lead or terminal and the hole wall to allow solder flow-through. (See Figure 5-11A.) The wall thickness of copper plating in the hole shall not be less than 0.001 inch.

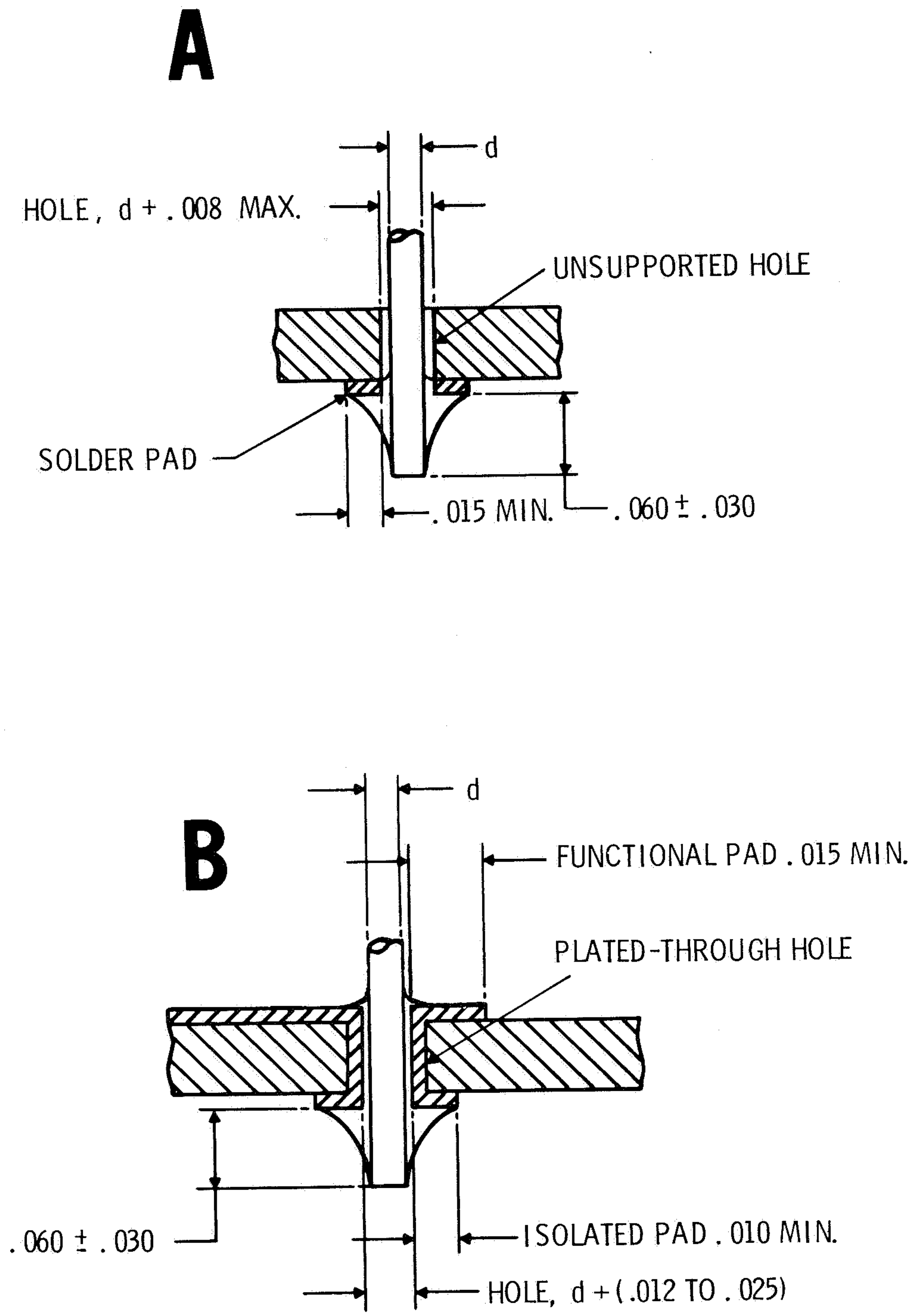


FIGURE 5-6
STUD TERMINATIONS

2. **Clinched Leads.** The lead shall extend through and overlap the solder pad a minimum of 3.5 times the lead diameter to a maximum of 5.5 times the lead diameter. The lead shall be bent in the direction of the longest dimensions of the solder pad provided by design, allowing nominal springback. However, if the pad dimensions are not sufficient, the lead shall be bent in the direction of the printed wiring path. A length of conductor pattern equal to 0.5 times the lead diameter shall be provided at the cut-off end of the lead to accommodate solder filleting. In instances where the component lead is less than .020 in diameter, lead overlap shall be no less than .062 inches. There shall be sufficient solder pad area extending beyond the sides of the lead to accommodate solder filleting. (See Figure 5-7.) In no case shall leads be temporarily constrained against the spring-back force during soldering so that the joint is subject to residual stress.

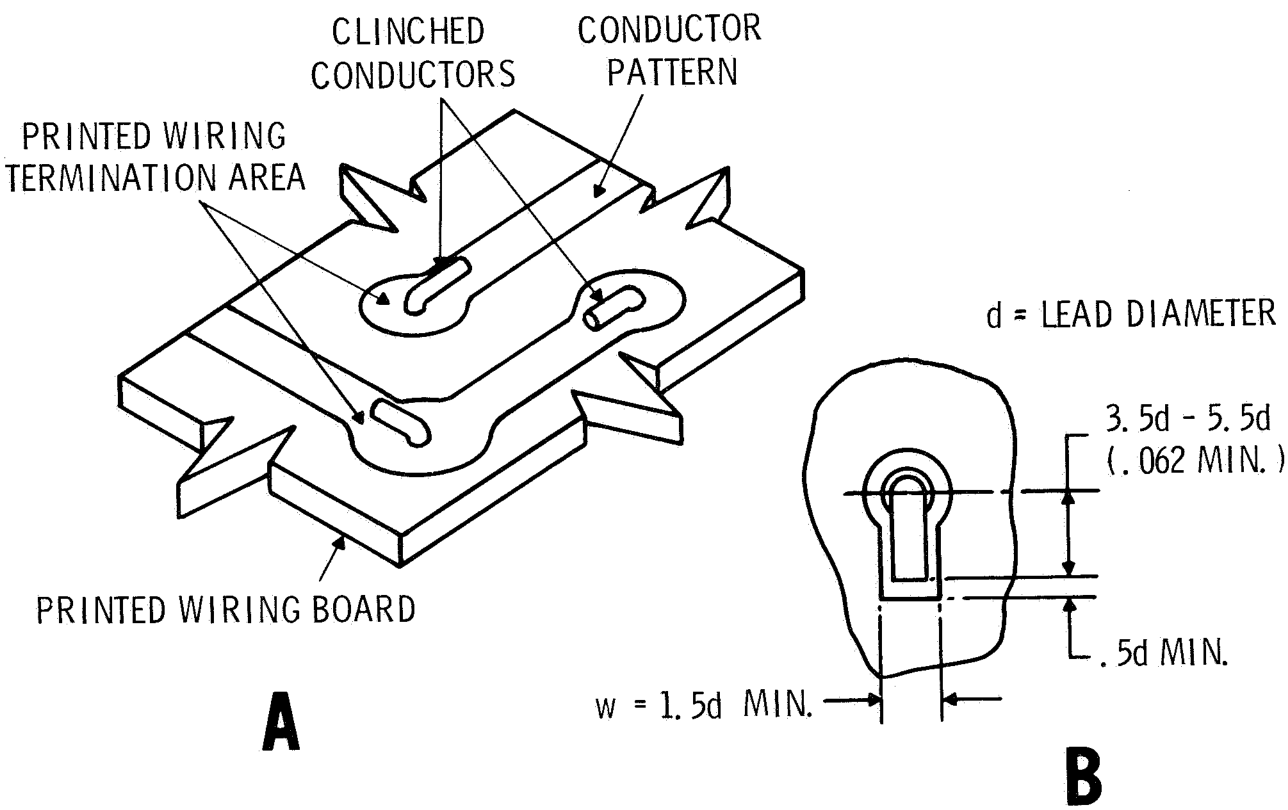
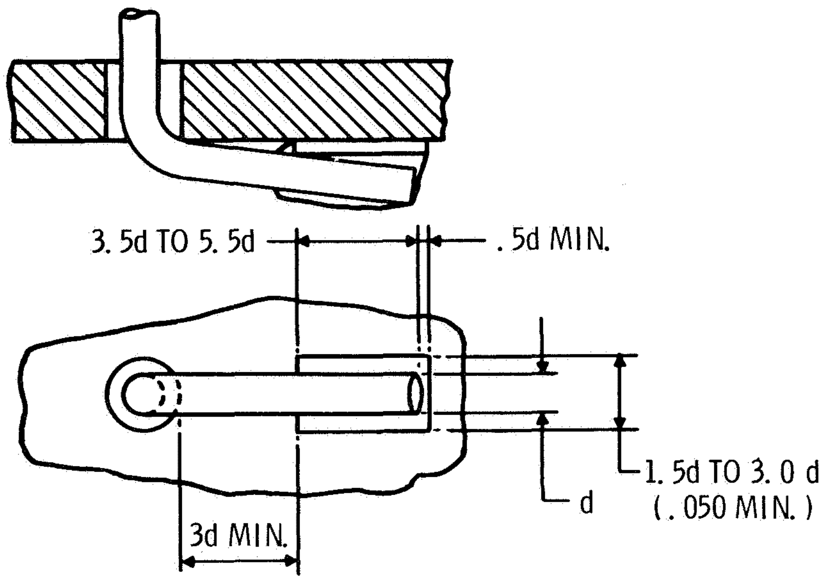


FIGURE 5-7

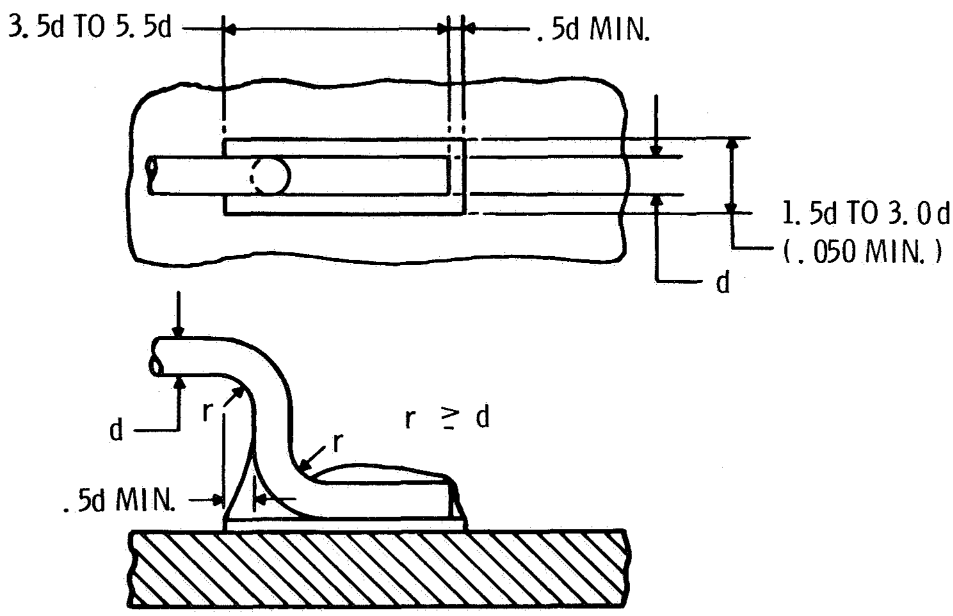
CLINCHED LEAD TERMINATIONS

3. **Stud Leads.** Leads which are not to be bent shall be cut so that when mounted the leads will protrude through the board circuitry 0.060" ± 0.030" (see Figures 5-6A and B).

4. **Lapped Round Leads.** The round lead shall overlap the solder pad a minimum of 3.5 times the lead diameter to a maximum of 5.5 times the lead diameter, but in no case shall be less than 0.050 inch. The cut-off end of the lead shall be no closer than 1/2 the lead diameter to the edge of the solder pad. Only that portion of the lead extending to the part body or to another soldered connection shall be beyond the solder pad. (See Figure 5-8.)



A. THROUGH-HOLE LAPPED TERMINATION



B. SINGLE SURFACE LAPPED TERMINATION

FIGURE 5-8
ROUND LEAD LAPPED TERMINATIONS

5. **Lapped Ribbon Leads.** The ribbon lead shall overlap the solder pad a minimum of 3 lead widths to a maximum of 5 lead widths. Only that portion of the lead extending to the part body or to another soldered connection shall be beyond the pad. The cutoff end of the lead shall be 0.010 inch minimum to the end of the pad. One edge of the lead may be flush with the edge of the solder pad. There shall be sufficient area around two of the three lead edges

to accommodate solder filleting (see Figure 5-9). In instances where ribbon leads are less than .020 inch in width, ribbon overlap shall be no less than .050 inch.

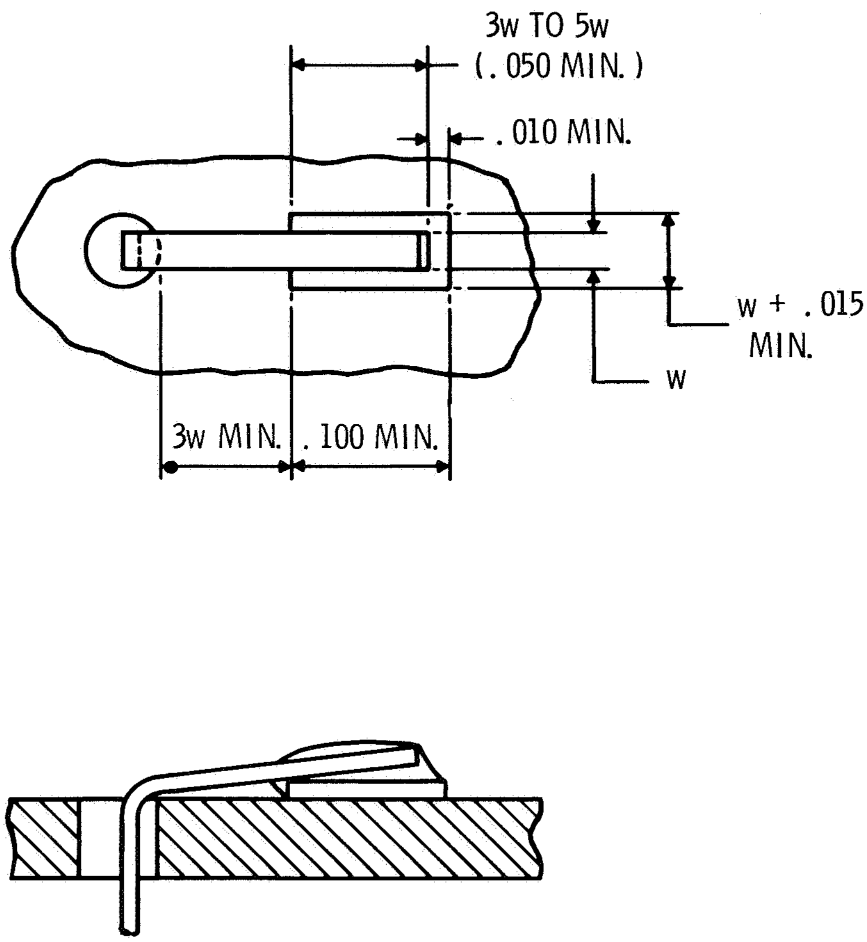


FIGURE 5-9

RIBBON LEAD, THROUGH HOLE LAPPED TERMINATION

6. **Lapped Round and Ribbon Leaded Parts with Solder Connection on Same Side.** Round or ribbon lead parts mounted on the same side as their solder connections shall have a minimum lead to solder pad contact of 3.0 times the lead diameter/ribbon width to a maximum of 5.5 times the lead diameter/ribbon width. (See Figures 5-8b and 5-10.) There shall be a minimum dimension of 0.5 of the lead diameter or ribbon width at the heel of the part lead to accommodate solder filleting. When soldered the heel fillets shall conform to the applicable workmanship standards.

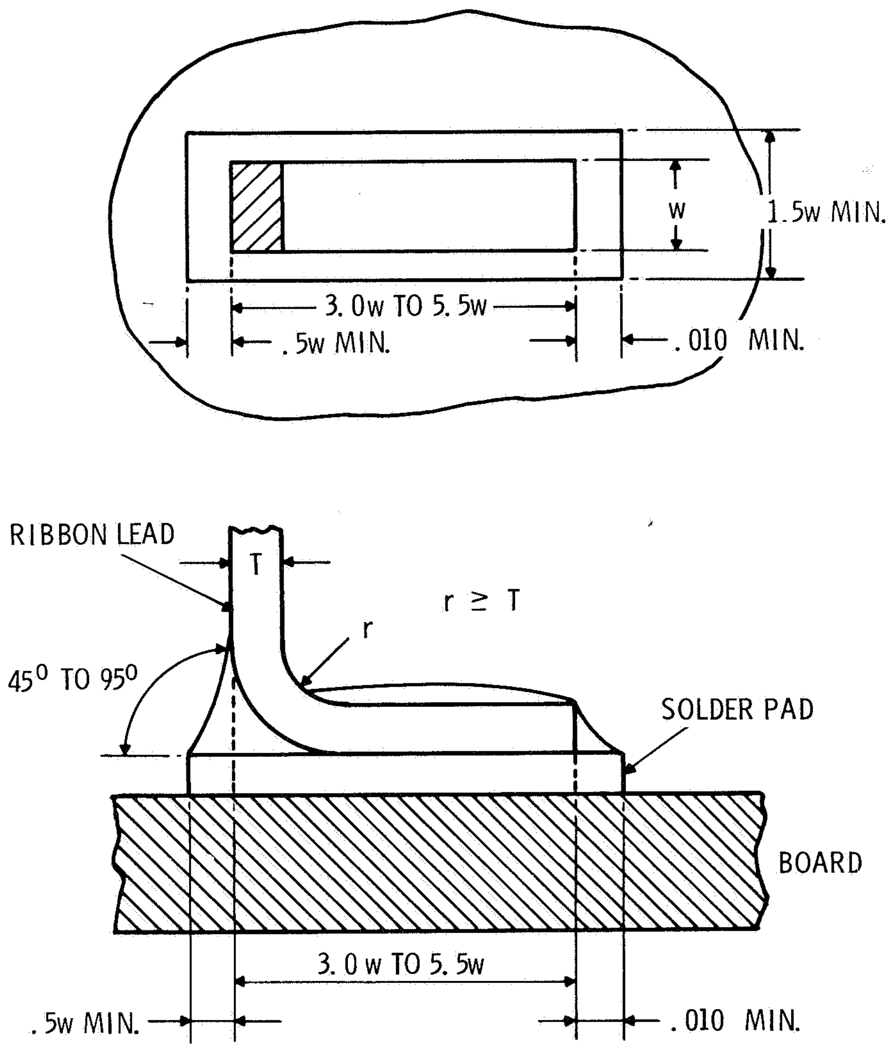
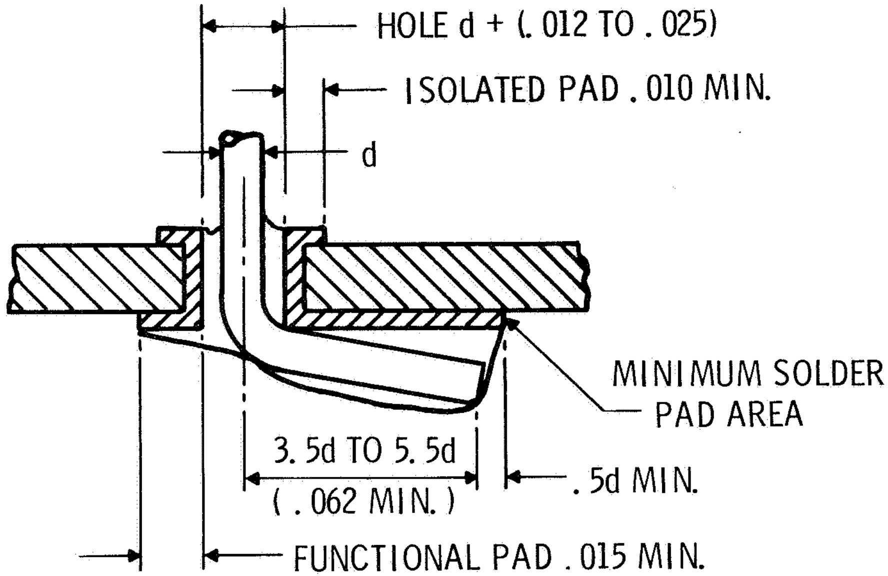
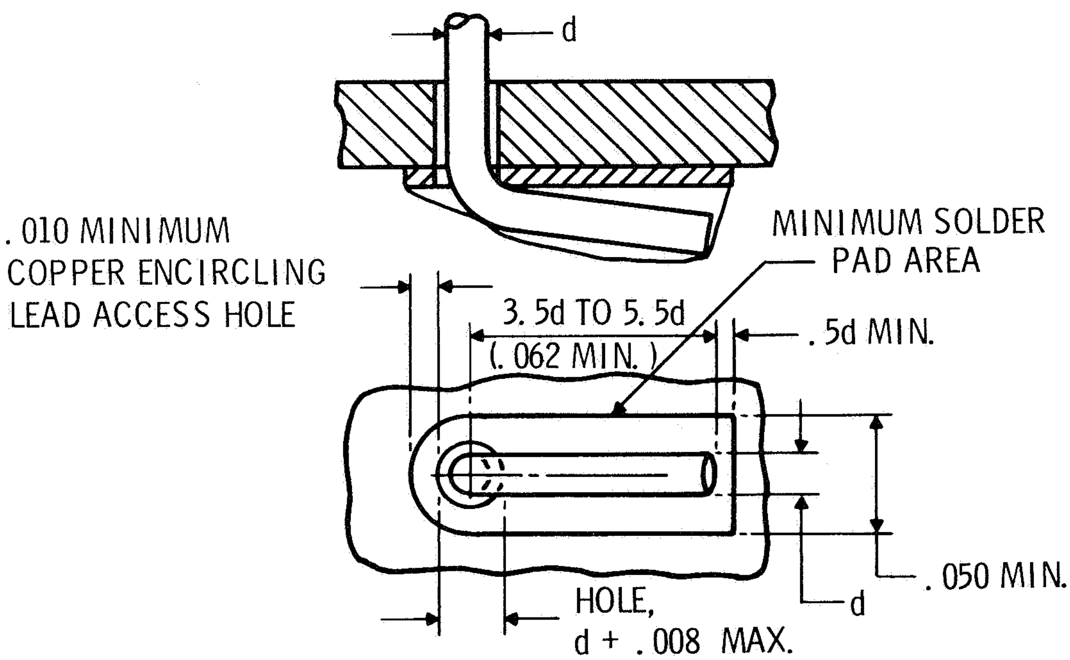


FIGURE 5-10

RIBBON LEAD, SINGLE SURFACE LAPPED TERMINATION



A. PLATED THROUGH-HOLE TERMINATION



B. UNSUPPORTED HOLE TERMINATION

FIGURE 5-11
ROUND LEAD, THROUGH HOLE CLINCHED TERMINATIONS

CHAPTER 6: ATTACHMENT OF CONDUCTORS TO TERMINALS

3A600 GENERAL

Conductors shall be attached to terminals as illustrated herein. For terminals not described or illustrated herein, similar procedures and inspection requirements for attachment of conductors shall be documented by the supplier and submitted for approval in accordance with par. 3A102-4.

1. **Breakouts from Cables.** For multiple wires routed from a common cable trunk to equally spaced terminals, the length of the wire ends, including vibration bend allowance shall be uniform to prevent stress concentration on any one wire.
2. **Minimum Insulation Clearance.** The insulation shall not be imbedded in the solder joint. The contour of the conductor shall not be obscured at the termination end of the insulation.
3. **Maximum Insulation Clearance.** The insulation clearance shall be less than two wire diameters including insulation but in no case shall permit shorting between adjacent conductors.
4. **Multiple Parallel Entry.** For multiple parallel entry of wires to a terminal, insulation clearances need not be equal.
5. **Variations.** When characteristic impedance or other circuit parameters are affected, such as in high voltage circuits or coaxial line terminations, the insulation clearance requirements may be modified. All variations shall be documented in the process procedures.
6. **Solid Hook-up Wire.** Solid hook-up wire shall not exceed a length of one inch between supports. Staking with resin or conformal coating is considered acceptable support. A single wire shall not be used to connect more than two points.
7. **Stress Relief.** Each conductor terminating at a solder connection shall have provision for stress relief to minimize stresses to the connection during thermal or mechanical variations.
8. **Mechanical Support.** Wire bundles shall be supported so that the solder connections are not subjected to mechanical loads.
9. **Splices.** Conductors shall not be spliced.
10. **Part Leads.** A part lead shall not be used as a terminal.

11. **Terminals.** Hot dipped, tin-lead coated terminals are preferred. Terminals with uneven or excessive coating on the mounting surfaces shall not be used as they may loosen in subsequent soldering operations. Terminals shall be of proper size to accommodate the conductors. Terminals and conductors shall not be modified to accommodate improper sizes.

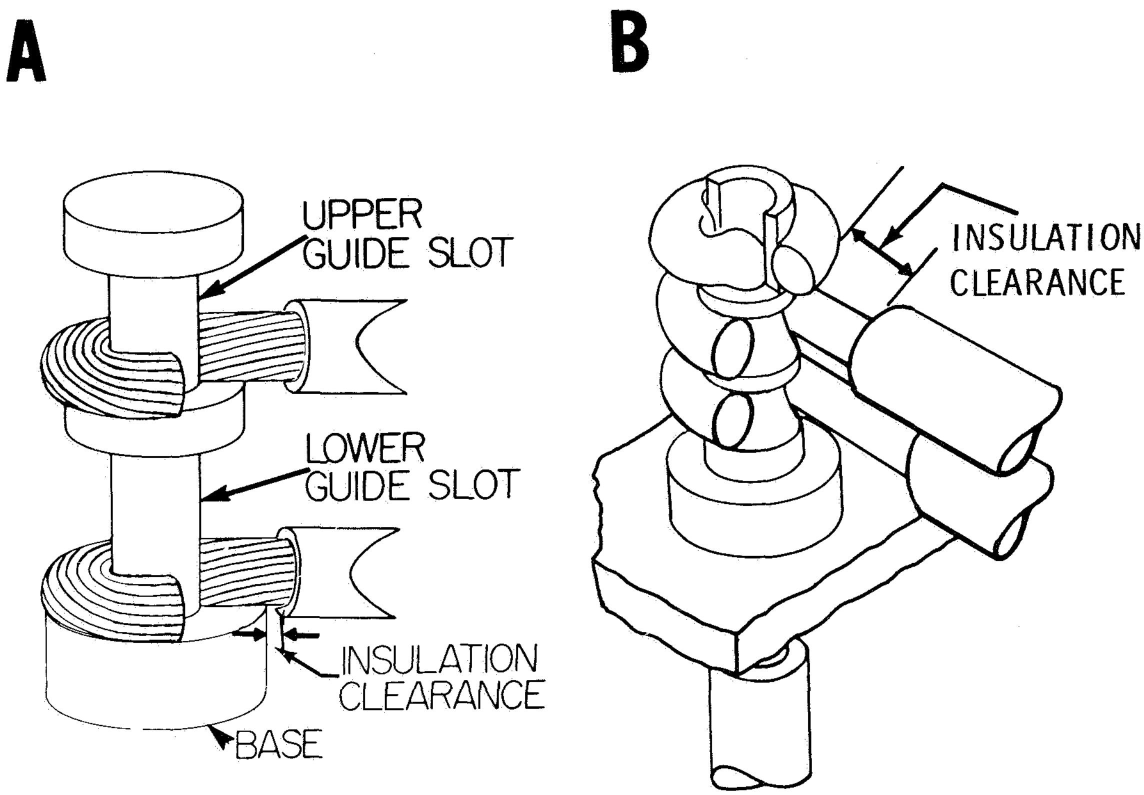


FIGURE 6-1

SIDE AND BOTTOM ROUTE CONNECTION TO TURRET TERMINALS

3A601 TURRET AND STRAIGHT PIN TERMINALS

1. **Side Route.** The side route shall be connected as follows (see Figure 6-1(a)):
   a. Conductor sizes AWG 26 and smaller shall be wrapped more than 1/2 turn but less than one full turn around the post.
   b. Conductor sizes larger than AWG 26 shall be wrapped more than 1/2 to a maximum of 3/4 turn around the post.
   c. For turret terminals, all conductors shall be confined to the guide slots.
   d. Conductors shall not extend beyond the base of the terminal.
   e. More than one wire may be installed in a single slot of sufficient width provided each wire is wrapped on the terminal post and not on another wire.
   f. Wires terminating to terminals that do not have a mechanical shoulder or turret shall not be attached closer than one conductor diameter to the top of the terminal.

2. **Bottom Route.** The conductor shall enter the terminal from the bottom, be brought through the side slot at the top, and wrapped as required for side route, see Figure 6-1(b).

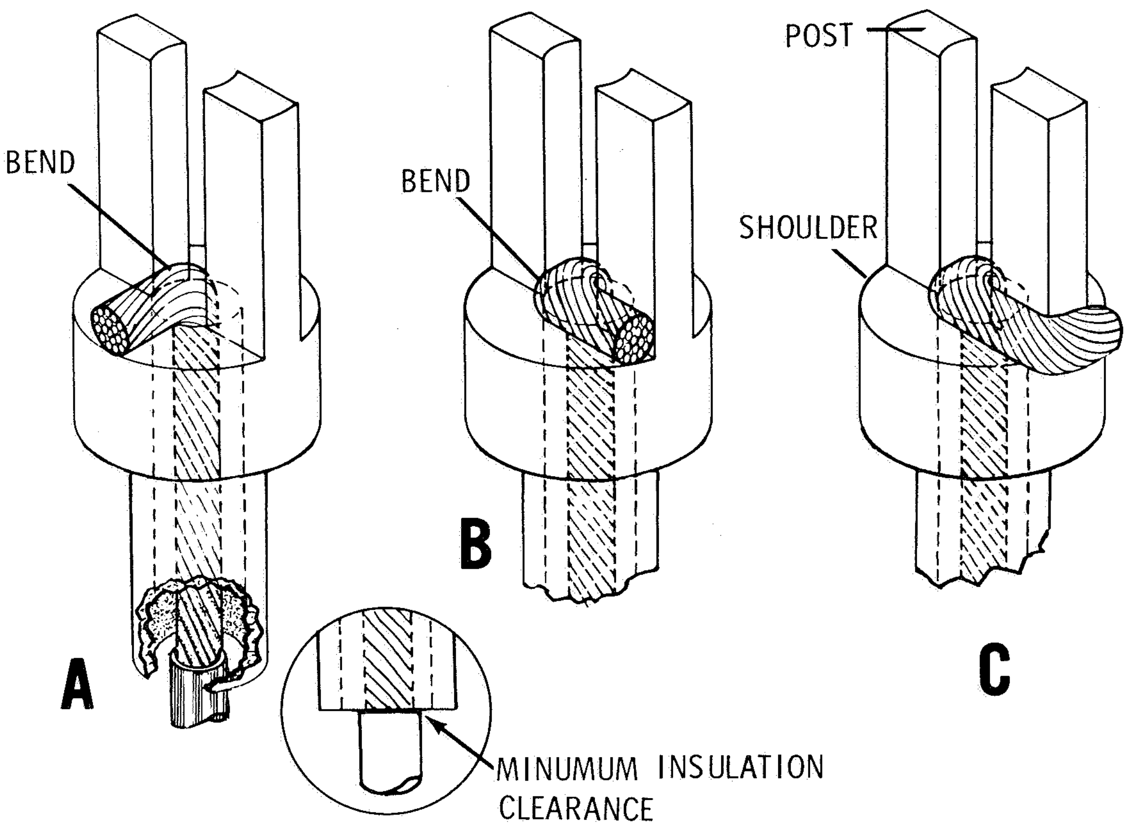


FIGURE 6-2

BOTTOM ROUTE CONNECTIONS TO BIFURCATED TERMINALS

3A602 BIFURCATED TERMINALS

1. **Bottom Route.** Bottom route shall be connected as shown in Figure 6-2. Conductors shall not extend beyond the diameter of the base except as shown in Figure 6-2(c), which is acceptable only when physical clearance is adequate for the intended environment and electrical characteristics.
2. **Side Route.** Side route shall be connected as shown in Figure 6-3. The conductor shall enter the mounting slot perpendicular to the posts. When more than one conductor is connected to a terminal, the direction of bend of each additional conductor shall alternate (Figures 6-3b or d). Conductors shall not extend beyond the diameter of the base except as shown in Figure 6-3(c), which is acceptable only where physical clearance is adequate for environment and electrical characteristics.
3. **Side and Bottom Route.** The bottom route shall be installed first as shown in Figure 6-2, then the side route as shown in Figure 6-3.

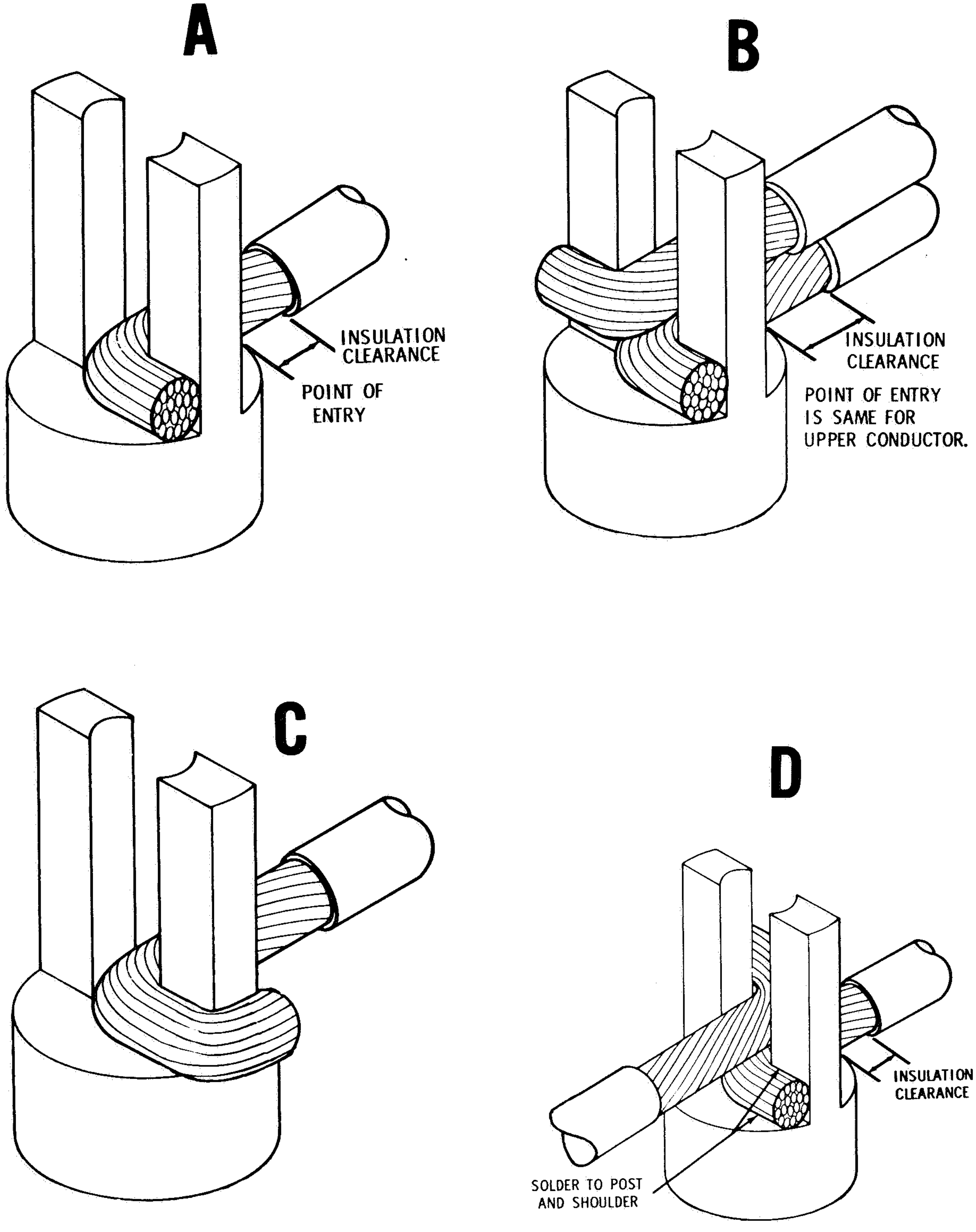
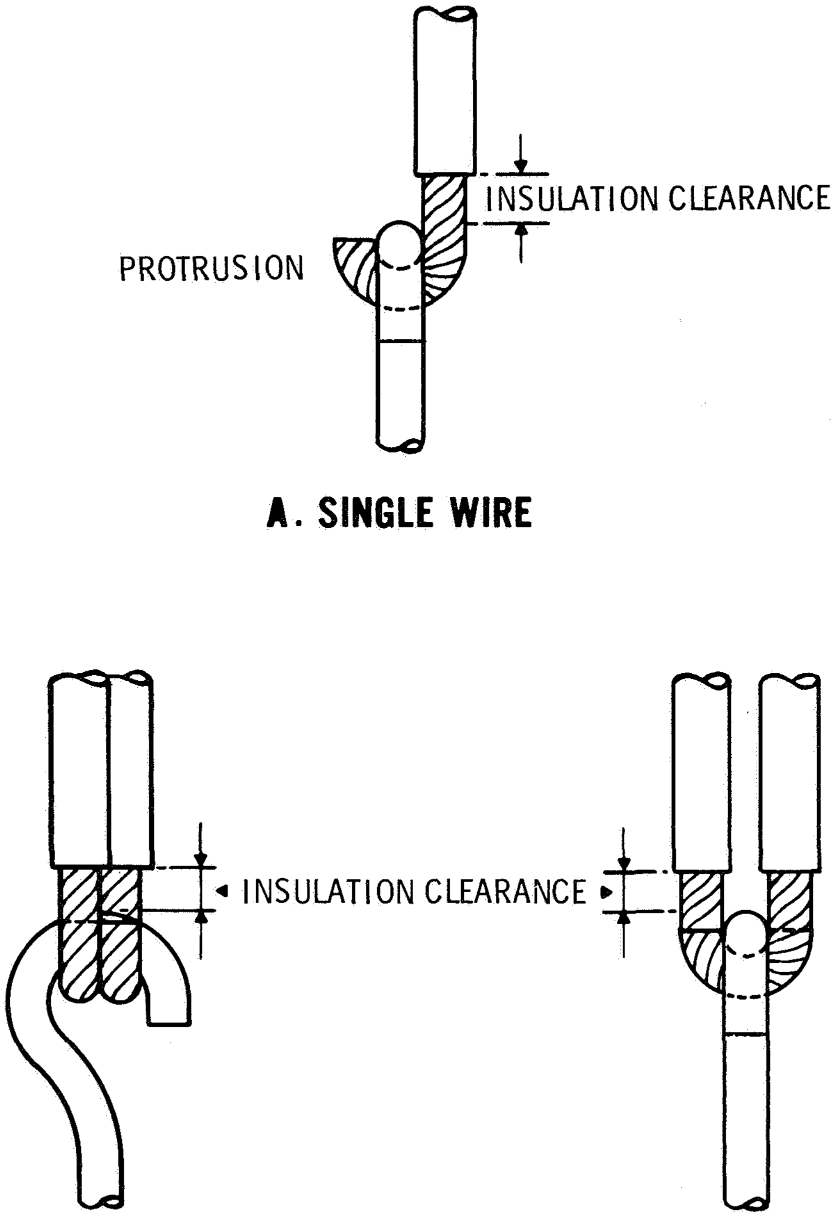


FIGURE 6-3
SIDE ROUTE CONNECTIONS TO BIFURCATED TERMINALS



B. MULTIPLE WIRE

FIGURE 6-4
CONNECTIONS TO HOOK TERMINALS

3A603 HOOK TERMINALS

Connections to hook terminals shall be as shown in Figure 6-4. The bend to attached conductors to hook terminals shall be a minimum of 1/2 turn to maximum of 3/4 turn. Protrusion of conductor ends shall be limited to avoid damage to insulation sleeving where used.

3A604 PIERCED TERMINALS

Connections to pierced terminals shall be as shown in Figure 6-5. The bend to attach conductors to pierced terminals shall be a minimum of 1/4 to a maximum of 3/4 turn. Protrusion of conductor ends shall be limited to avoid damage to insulation sleeving where used.

3A605 SOLDER CUPS (CONNECTOR TYPE)

Conductors shall enter the solder cup as shown in Figure 6-6. Conductors shall be bottomed in the cup and shall be in contact with the inner wall of the cup. The maximum number of conductors shall be limited to those which can be in contact with the full height of the inner wall of the cup.

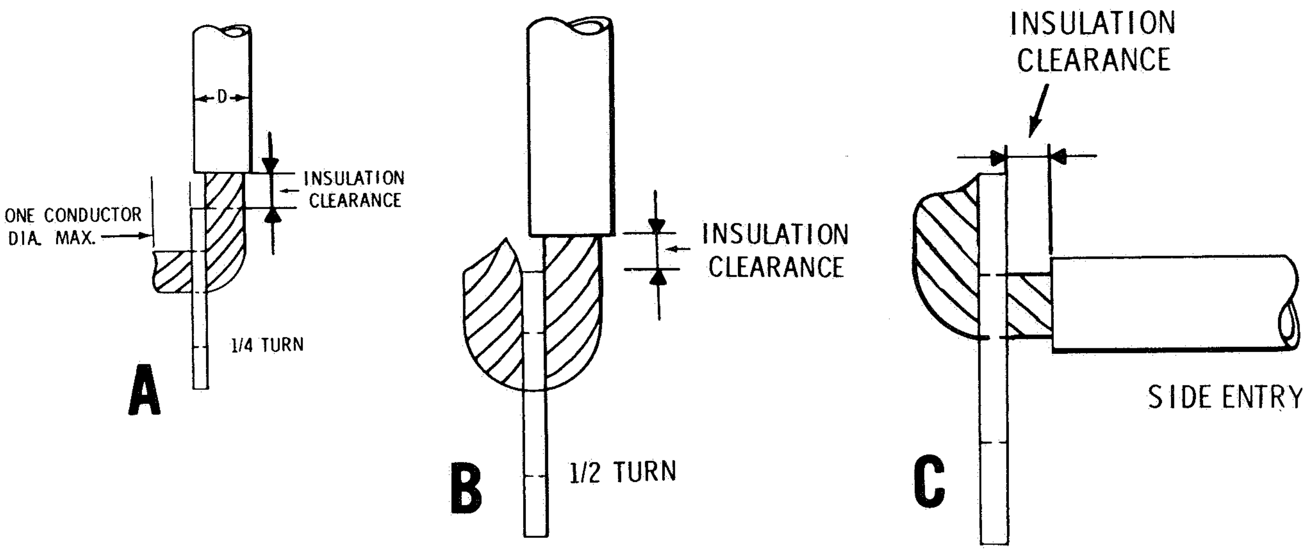


FIGURE 6-5
CONNECTIONS TO PIERCED TERMINALS

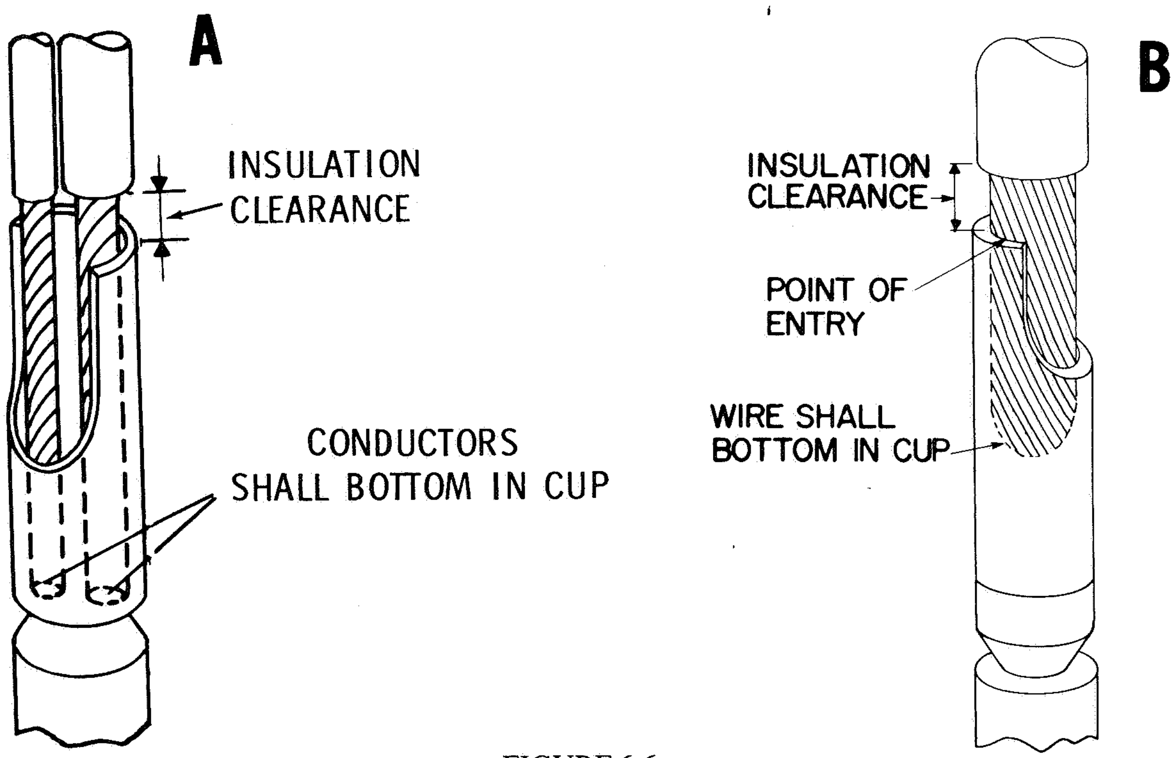


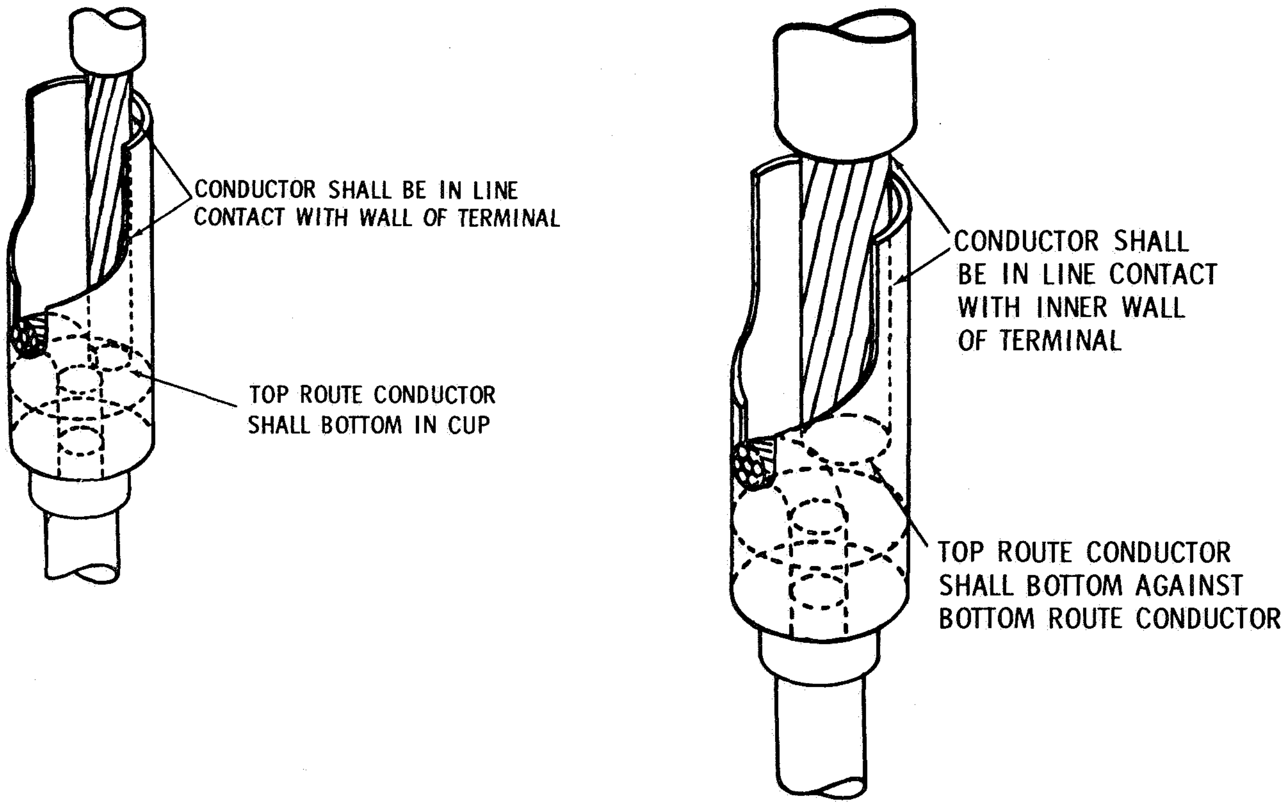
FIGURE 6-6
CONNECTIONS TO SOLDER CUPS (CONNECTOR TYPE)

3A606 SOLDER CUPS (SWAGED TYPE)

Connection shall be as shown in Figure 6-7. Conductors entering from the top shall be in contact with the inner wall of the cup and shall bottom in the cup or on the bottom conductor.

3A607 CONNECTION WITHOUT TERMINALS

When solid conductors such as transformer leads, connector pins, or module pins are approved by the procuring NASA installation to be used as straight pin type terminals, conductors shall be terminated as specified in par. 3A601; i.e., the lead shall be treated as a nonshouldered turret terminal.



A—SMALL UPPER CONDUCTOR

B—LARGE UPPER CONDUCTOR

FIGURE 6-7

CONNECTIONS TO SWAGED TYPE SOLDER CUPS

3A608 INSULATION TUBING APPLICATION

Heat shrinkable transparent insulation tubing shall be used for electrical insulation, as appropriate. For example, hook terminals, solder cups and bus wires which are not protected by insulating grommets, potting, or conformal coating shall be protected by insulating tubing. Where a part covered by insulating tubing requires mechanical support, measures shall be taken to ensure that the part is not free to move within the tubing.

CAUTION

EXTREME CARE SHALL BE TAKEN TO PREVENT DAMAGE TO THE ASSEMBLY DUE TO EXCESSIVE HEAT WHILE SHRINKING THE TUBING.

CHAPTER 7: SOLDERING TO TERMINALS

3A700 GENERAL

1. **Securing Conductors.** There shall be no relative motion between conductors and the terminal during soldering and while the solder is solidifying. Conductors shall not be temporarily constrained against spring-back force during solder solidification so as to produce residual stress in the joint.
2. **Thermal Shunts.** Thermal shunts shall be used where heat during the soldering operations may degrade conductors, insulation, parts, or previously soldered connections.
3. **High Voltage Connections.** High voltage connections where corona suppression is necessary shall be as defined in design documentation. Where soldering of high voltage connections is required, all elements of the connection shall be covered by a smooth fillet, free of discontinuity or severe change in contour.

3A701 SOLDER APPLICATION

1. **Cup Terminals**
   a. The solder shall form a fillet between the wire and cup entry slot. The fillet shall follow the contour of the cup opening within the limits illustrated in the satisfactory solder connections, Appendix B.
   b. Solder spillage along the outside surface of the solder cup is permissible to the extent that it approximates tinning and does not interfere with the assembly or functions of the connector.
2. **All Terminals Except Cup**
   a. A fillet of solder shall be formed between the terminal and each side of the wire.
   b. Terminals with more than one wire shall have each wire in contact with and soldered to the terminal.
3. **Wicking.** Flow (wicking) of solder along the wire is permitted. Solder shall not make the presence of the individual wire strands at the termination of the insulation indistinguishable.

3A702 REMOVAL OF FLUX AND RESIDUE

After the solder has solidified and cooled, flux and residue shall be carefully removed from each solder connection using a solvent as specified in 3A311. Solvent shall be applied in a manner that will minimize entry of solvent under wire insulation and prevent its entry into the interior of parts.

3A703 INSPECTION

Each soldered connection shall be visually inspected in accordance with the criteria of this chapter. Inspection shall be aided by magnification appropriate to the size of connections between 4X and 10X magnification. Additional magnification shall be used as necessary to resolve suspected anomalies or defects. Parts and conductors shall not be physically disturbed to aid inspection. Inspection standards for typical soldered connections are shown in Appendix B.

3A704 ACCEPTANCE CRITERIA

An acceptable solder connection will be characterized by:

1. Clean, smooth, bright, undisturbed surface;
2. Solder fillet between wire or lead and termination as described and illustrated herein;
3. Contour of wire sufficiently visible to determine the presence of the wire, the direction of the bend, and the terminating end of the wire (except high voltage connections; see par. 3A700-3);
4. Complete wetting;
5. Proper amount and distribution of solder; and
6. Absence of the defects enumerated in par. 3A705.

3A705 REJECTION CRITERIA

The following are some characteristics of unsatisfactory solder conditions, any of which is cause for rejection:

1. **Conductors and Parts:**
   a. Damaged, crushed, cracked, charred, or melted insulation.
   b. Improper insulation clearance.
   c. Improper tinning.
   d. Separation of wire strands.
   e. Part improperly supported or positioned.
   f. Part marking not visible.
   g. Part damaged.
   h. Loose conductors.
   i. Cut, nicked, stretched, or scraped leads or wires.
   j. Flux residue or other contaminations.
   k. Improper wrap or stress relief.
   ℓ. Spliced conductors.

2. **Solder Connections:**

   a. Cold joint.

   b. Overheated granular joint.

   c. Fractured joint.

   d. Improperly bonded joint.

   e. Pitted or porous joint.

   f. Excessive solder.

   g. Insufficient solder.

   h. Splattering of flux or solder on adjacent areas.

   i. Rosin solder connection.

   j. Unclean connection (e.g., lint, flux, dirt, etc.).

   k. Dewetting.

CHAPTER 8: SOLDERING OF PRINTED WIRING ASSEMBLIES

3A800 GENERAL

1. **Securing Elements.** There shall be no relative motion between conductors, part leads, terminals, and printed wiring board (PWB) termination areas during solder application and solidification. However, the method used to immobilize the elements during the soldering operation shall not result in the holding of part leads against normal springback forces or deforming PWB's such that resulting solder joints contain residual stresses.
2. **Thermal Shunts.** Thermal shunts shall be used where heat during the soldering operations may degrade conductors, insulation, parts, or previously soldered connections.
3. **Dip Soldering.** Manual dip soldering of printed wiring assemblies is not permitted.
4. **Pattern Repair.** Repair of damaged or broken conductor patterns on PWB's is not permitted.
5. **Solder Rework.** Rework of soldered printed wiring assemblies shall be performed in accordance with the soldering requirements of this publication.
6. **High Voltage Connections.** High voltage connections where corona suppression is necessary shall be as defined in design documentation. Where soldering of high voltage connections is required, all elements of the connection shall be covered by a smooth fillet, free of discontinuity or severe change in contour.

3A801 SOLDER APPLICATION

1. **Solder Coverage.** The molten solder shall flow around the conductor and over the termination area. Solder quantity shall be as shown in Appendix B except for high voltage connections, which shall be as prescribed in par. 3A800-6.
2. **Solder Fillets.** Solder filleting shall be complete and as illustrated in Appendix B. On lap terminations where one side of a ribbon lead is flush with the edge of the termination pad, a fillet of solder shall be present along at least 3 of the 4 sides of the lead. Where a part is mounted on the same side as the lap termination, a heel fillet is required where the ribbon or round lead bends away from the pad. The fillet of solder along the lead shall extend up the side of the lead a minimum distance of 1/2 the lead thickness or diameter.

3. **Plated-Through-Hole (Reinforced Hole) Soldering.** When soldering a termination configuration that incorporates a plated-through-hole (PTH) on a two-sided PWB, a solid wire shall be used as an interfacial connection. In soldering the conductor in the PTH, heat and solder shall be applied only on that portion of the PTH that is attached to the printed conductor. The solder shall completely flow through and fill the PTH. Under no circumstances shall the heat and solder be applied to both sides of the PTH. The connection on the heat and solder application side of the PTH shall meet all the requirements established by this document. For the connection on the opposite side:

   a. On functional pads, the solder shall form a complete fillet between lead and solder pad and show evidence of complete solder wetting around the lead and on to the pad.

   b. On non-functional pads, the solder shall show evidence of flow-through and bonding of the lead to the pad (not necessarily wetted around the entire periphery of the hole).

3A802 REMOVAL OF FLUX AND RESIDUE

After the solder has solidified and cooled, flux and residue shall be carefully removed from each soldered connection using a solvent specified in par. 3A311. Solvent shall be applied in a manner that will minimize entry of solvent under wire insulation and prevent entry into the interior of parts.

3A803 INSPECTION

Each soldered connection shall be visually inspected in accordance with the criteria of this Chapter. Inspection shall be aided by magnification appropriate to the size of connections, between 4X and 10X magnification. Additional magnification shall be used as necessary to resolve suspected anomalies or defects. Parts and conductors shall not be physically disturbed to aid inspection. Inspection standards for typical soldered connections are shown in Appendix B.

3A804 ACCEPTANCE CRITERIA

Acceptable solder connections on printed wiring assemblies will be characterized by:

1. Clean, smooth, bright undisturbed surface,
2. Solder fillets between conductor and termination areas as described and illustrated herein (for plated-through hole connections, see criteria in par. 3A801-3),
3. Contour of wire sufficiently visible to determine presence of the wire, the direction of the bend and the termination end of the wire (except high voltage connections; see par. 3A800-6),
4. Complete wetting,
5. Proper amount and distribution of solder, and
6. Absence of the defects enumerated in par. 3A805.

3A805 REJECTION CRITERIA

The following are some characteristics of unsatisfactory conditions any of which is cause for rejection:

1. Charred, burned, or melted insulation or parts.
2. Conductor pattern separation from board.
3. Burns on base materials.
4. Discoloration which is continuous between printed conductors (e.g., measling, delamination, halo effect, etc.)
5. Excessive solder (including peaks, icicles, and bridging).
6. Flux residue, solder splatter, or other foreign matter on circuitry or adjacent areas.
7. Dewetting.
8. Insufficient solder.
9. Pits, holes or voids, or exposed base metal in the soldered connection.
10. Cold, rosin, granular or disturbed solder connection.
11. Fractured or cracked solder connection or evidence of grain structure change.
12. Cut, nicked, gouged, or scraped conductors or printed wiring conductor pattern.
13. Improper conductor length or direction of clinch.
14. Repaired or damaged printed wiring conductor pattern.

CHAPTER 9: AUTOMATIC MACHINE SOLDERING

3A900 GENERAL

This chapter contains requirements peculiar to automatic machine soldering.

1. The supplier's procedures for automatic machine soldering operations shall set limits on the:

   a. Preheat temperature,

   b. Temperature of the solder,

   c. Conveyor speed,

   d. Height of the solder wave,

   e. Control of the dross inhibition oil and flux (if fluxing is done as a machine step),

   f. Contaminants permissible when the solder bath is analyzed,

   g. Frequency of maintenance and of analysis and other factors affecting the quality of the connections in the end-product.

   Maintenance and calibration data shall be recorded and available to Government and supplier inspection.

2. **Solder.** The solder used shall be tin-lead conforming to composition SN-60 or SN-63, type S of QQ-S-571.

3. **Flux.** Liquid flux solutions shall be specified as to composition and concentration. Concentration shall be controlled within specified limits by periodic measurement (e.g., specific gravity determination) and adjustment on a predetermined schedule.

   a. **Rosin base flux.** This soldering flux shall be non-corrosive, nonconductive and meet requirements specified in par. 3A310-2. A compatible thinner solution may be added to liquid rosin flux.

   b. **Water soluble flux.** This flux shall be an organic composition (acid, halogen, amine or amide) and moderately active. It shall have been demonstrated to be noncorrosive when used in the machine soldering application and be readily removed by water. Prior approval by the NASA procuring installation must be obtained for the use of this flux.

4. **Solvents.** Water with a wetting agent additive or other solvents specified in 3A311 shall be used as appropriate for cleaning printed wiring assemblies. However, use of wetting agents should be followed by thorough deionized water rinse and thorough drying. Assemblies must then be kept dry until conformally coated.

5. **Oil.** When oil is used to reduce surface tension and oxidation of the liquid solder, it shall be selected using the following criteria:

   a. Thermal stability or low evaporation loss.

   b. Length of "use life", before a change is necessary.

   c. Weight loss.

   d. Boiling point.

   e. Wetting ability.

   f. Ease of removal from PWB assembly after soldering operation.

   Additives allowed in the oil are oxidation inhibitors, wetting agents and dross scavengers (fatty acids).

3A901 PREPARATION AND ASSEMBLY

1. Only tin-lead (solder) coated or reflowed electroplated tin-lead coated conductor patterns shall be used in machine soldering of printed wiring assemblies.

2. Parts shall be mounted as specified in Chapters 5 and 6 of this document. The mounting shall prevent relative motion between part and board during solder solidification. If temporary clamping is used, it shall not result in residual solder joint stresses from lead springback forces.

3. The assembled boards shall be cleaned immediately prior to loading onto the carrier.

4. Metal surfaces not to be soldered shall be masked or coated with a solder resist prior to loading.

3A902 MACHINE SOLDERING

1. The preheat temperature shall be controlled to a selected board temperature between 160° and 225°F. The selected temperature shall be maintained within ± 5°F.

2. The conveyor speed shall be controlled to a preselected rate, which shall not vary more than 1 inch per minute.

3. Solder temperature shall be controlled so that the solder in the wave making contact with the board is 480° to 525°F.

4. The height of the solder wave shall be controlled to a constant preselected height.

5. The solder bath shall be analyzed on an established schedule based on usage, to ensure that solder composition is not contaminated with copper in excess of 0.25 percent by weight or gold in excess of 0.2 percent, with the total of gold plus copper not to exceed 0.3 percent. Contamination with zinc, cadmium, aluminum or iron is to be carefully avoided. When the solder produces a dull, frosty or granular appearance on the work, the bath shall be removed from use.

6. The oil shall be analyzed on an established schedule based upon usage to determine the rate of degradation and the oil replacement period.
7. A machine soldering log shall be maintained showing preheat temperature, conveyor speed, solder temperature range and wave height for each PWB type in order to repeat previously successful runs. The log shall also be used to document results of analyses prescribed in paragraphs 5 and 6 above.

3A903 CLEANING

1. After soldering, the flux, dross inhibitor, solder-resist and oil shall be promptly removed in a manner which does not damage the hardware. This shall be accomplished by use of an appropriate solvent meeting the requirements of par. 3A311, followed by rinsing with clean solvent to ensure complete removal of the residues.
2. Where water-soluble fluxes are used, the cleaning operation is especially critical because residual flux results in electrical leakage paths and corrosion. In this case, there shall be no delay between cooling of the board to the temperature of the cleaning solvent and cleaning, or between cleaning and rinsing with deionized water in a controlled rinse bath. The final rinse bath shall be controlled by resistivity measurement made at established intervals to pre-established resistivity limits. Intervals shall be based on the number and size of boards cleaned as well as time.

3A904 INSPECTION

Inspection criteria listed in Chapters 7 and 8 are applicable to machine soldered assemblies. Warp or twist of the board shall not exceed the limits specified by the detail drawing.

CHAPTER 10: VERIFICATION

3A1000 GENERAL

When prescribed by the procuring NASA installation, verification tests shall be conducted to establish confidence in the reliability of solder joint configurations not shown in this document. The configuration is considered verified if there are no cracked solder joints or part damage found after 200 thermal cycles in accordance with temperature cycling and vibration testing (listed below) when examined under 15X minimum magnification.

1. **Temperature Cycling.** The test specimen shall be temperature cycled in an air circulating oven from room temperature to −55° to 100°C and back to room temperature at a rate not to exceed 5°C per minute. Soak time at each temperature extreme should be 15 minutes. The duration of each cycle should average two hours. These conditions may be modified by the procuring NASA installation to conform with the particular environmental qualification conditions for the assembly being verified.
2. **Vibration.** After completion of the temperature cycling, the test specimen shall be subjected to vibration. The procuring NASA installation will prescribe test levels, frequencies and durations.

APPENDIX A

DEFINITIONS

The following definitions apply to terms used in this Handbook:

Article. A unit of hardware or any portion thereof required by the contract.

Bifurcated (split) Terminal. A terminal containing a slot or split in which wires or leads are placed before soldering.

Blister. Delamination in distinct local areas.

Bridging. A build-up of solder or conformal coating between parts, part leads and/or base substrate forming an elevated path (See fillet).

Certification. The act of delegated authority in verifying and documenting that personnel have completed required training and have demonstrated specified proficiency and have met other specified requirements.

Cold Solder Joint. Unsatisfactory connection resulting from dewetting or movement of conductor during cooling and frequently exhibiting an abrupt rise of the solder from the surface being soldered. These usually appear frosty and granular.

Conduction Soldering. Method of soldering which employs a soldering iron for transfer of heat to the soldering area.

Conductor. A lead or wire, solid or stranded, or printed wiring path serving as an electrical interconnection between terminations.

Conformal Coating. A thin electrically nonconductive protective coating which conforms to the configuration of the covered assembly.

Connection. An electrical termination.

Contractor. The individual(s) or concern(s) who enter into a prime contract with the Government.

Cracked Solder Joint. A soldered connection which has fractured or broken within the solder.

Delamination. A distinct separation of PWB layers (resin from glass).

Deviation. A specific authorization, granted before the fact, to depart from a particular requirement of specifications or related documents.

Dewetting. The condition in a soldered area in which the liquid solder has not adhered intimately, characterized by an abrupt boundary between solder and conductor, or solder and terminal/termination area.

Disturbed Solder Joint. Unsatisfactory connection resulting from relative motion between the conductor and termination during solidification of the solder.

Electrical Component. An assembly of one or more electronic/electrical parts that may be disassembled or separated without destruction of designed use, e.g., printed wiring assembly.

Encapsulating Compound. An electrically nonconductive compound used to completely enclose and fill in voids between electrical components or parts.

Excessive Solder Joint. Unsatisfactory connection wherein the solder obscures the configuration of the connection.

Eyelet. A tubular metal part having both ends headed or rolled over.

Fillet. A smooth concave build-up of material between two surfaces; e.g., a fillet of solder between a part lead and a solder pad or terminal, or a fillet of conformal coating material between a part and a PWB.

Fractured Solder Joint. A joint showing evidence of cracking.

Hook Terminal. A terminal formed in a hook shape.

Interfacial Connection. A conductor which connects conductive patterns between opposite sides of a printed wiring board.

Joint. A solder joint; a termination.

Mission Essential Support Equipment. Equipment used in a closed loop with the system, where failure of this equipment would degrade the mission or imperil personnel. This includes items of ground support equipment whose functions are necessary to support the countdown phase and those items of ground support equipment used in pre-countdown phases whose problems can create a safety hazard, cause damage to flight hardware or inability to detect a problem on the flight hardware.

Overheated Joints. An unsatisfactory solder joint, characterized by rough solder surface.

Pad. A solder pad.

Part. One piece, or two or more pieces joined together which are not normally subject to disassembly without destruction of designed use. Synonymous with detail part and component part (e.g., resistor, capacitor, valve, relay).

Part Lead. The conductor, solid or stranded, attached to a part.

Plated-Through-Hole (PTH). A plated-through hole is one formed by a deposition of metal on the inside surface of the hole. Also known as a supported hole. The configuration is used to provide additional mechanical strength to the soldered termination or to provide an electrical interconnection on a multilayer printed wiring board.

Porous Solder Joint. A joint having a grainy or gritty surface.

Potting Compound. An electrically nonconductive compound used to partially encapsulate or for a filler between parts, conductors, or assemblies.

Pierced (Perforated) Terminal. A terminal containing a hole through which leads or wires are placed before soldering.

Pits. Small holes or sharp depressions in the surface of the solder.

Printed Wiring Board (PWB) Assembly. The PWB assembly consists of the printed wiring board, parts, and associated hardware and materials.

PTH. Plated-through-hole.

PWB. Printed wiring board.

Repair. Operations performed on a nonconforming article to place it in usable condition. Repair is distinguished from rework in that alternate processes rather than reprocessing are employed.

Resistance Soldering. Method of soldering by passing a current between two electrodes through the area to be soldered.

Rework. The reprocessing of articles or material that will make it conform to drawings, specification or contract.

Rosin Solder Joint. Unsatisfactory connection which has entrapped rosin flux.

Solder. A nonferrous, fusible metallic alloy used to join metallic surfaces.

Solder Cup Terminal. A hollow, cylindrical terminal to accommodate one or more conductors.

Solder Icicle. A cone shaped peak or sharp point of solder usually formed by the premature cooling and solidification of solder upon removal of the heat source.

Solder Joint. A termination.

Solder Pad. Termination area on a printed wiring conductor.

Soldering. The process of joining metallic surfaces through the use of solder without direct fusion of the base metals.

Staking Compound. An electrically nonconductive adhesive material used to anchor a part or component in place.

Straight Pin Terminal. A round post-type smooth terminal, with no grooves.

Stud Termination. An upright conductor termination through a printed wiring board.

Stress Relief. Method or means to minimize stresses to the soldered termination or part.

Subcontractor. The individual(s) or concern(s) who enter into a purchase agreement under a Government prime contract.

Supplier. A contractor or subcontractor actually performing the services or producing the contract articles.

Terminal. A tie point device used for making electrical connections.

Termination. The point at which electrical conductors are joined.

Termination Area. A conductive surface on a printed wiring board used for making electrical connections (also referred to as a solder pad).

Thermal Shunt. A device with good heat dissipation characteristics used to conduct heat away from an article being soldered.

Tinning. The coating of a surface with a uniform layer of solder.

Tubelet. A tubular metal part. Its ends may or may not be flared.

Turret Terminal. A round post-type grooved stud around which conductors are fastened before soldering.

Waiver. Granted use, or acceptance, of an article which does not meet specified requirements.

Wetting. Flow and adhesion of a liquid to a solid surface, characterized by smooth, even edges, and a low dihedral angle.

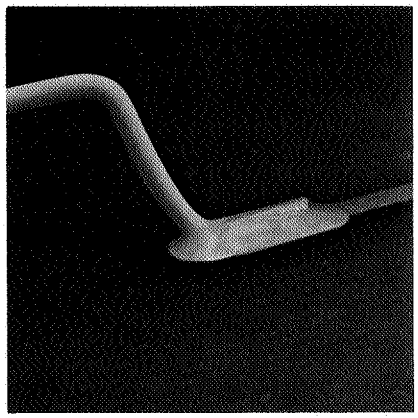
Wicking. A flow of molten solder or cleaning solution by capillary action.

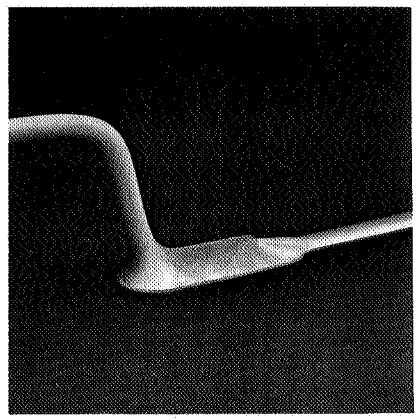
APPENDIX B

TYPICAL ACCEPTABLE SOLDER CONNECTIONS

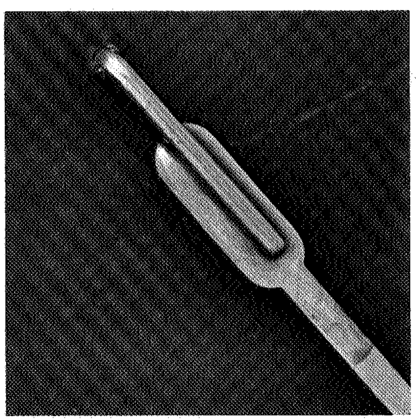
The Illustrations in this Appendix depict acceptable maximum and minimum amounts of solder on typical solder connections. They are to be used as visual workmanship standards. See Chapters 7, 8, and 9 for specific inspection criteria.

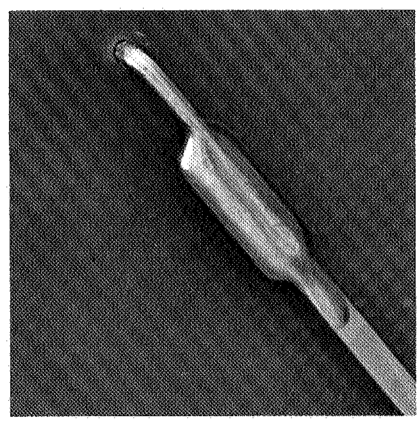
Minimum | Maximum





PWB LAPPED TERMINATION
Round Lead From Same Side of Board to Rectangular Pad

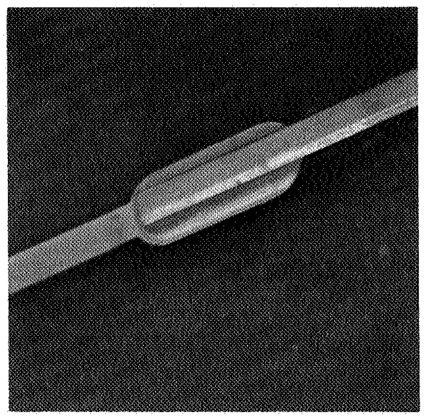


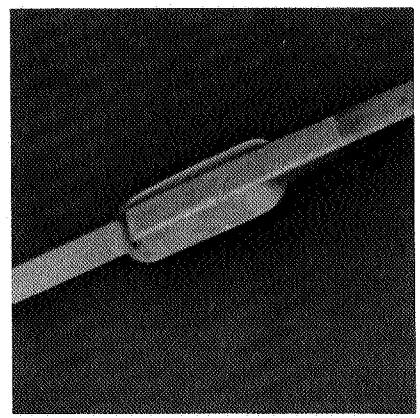


PWB LAPPED TERMINATION
Round Lead Through the Board to Rectangular Pad

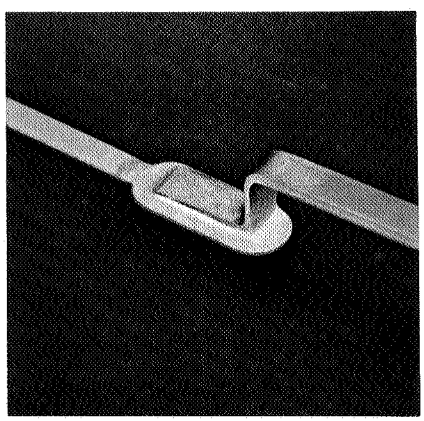
Minimum

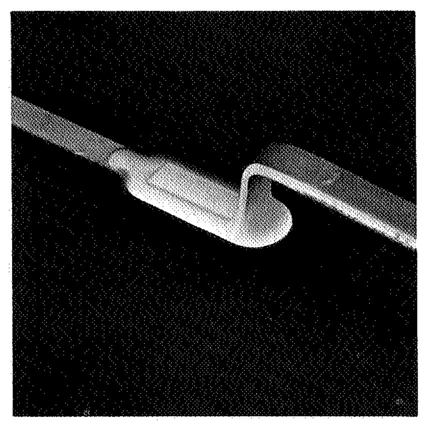
Maximum





PWB LAPPED TERMINATION
Ribbon Lead Through the Board (Simulated) to Rectangular Pad

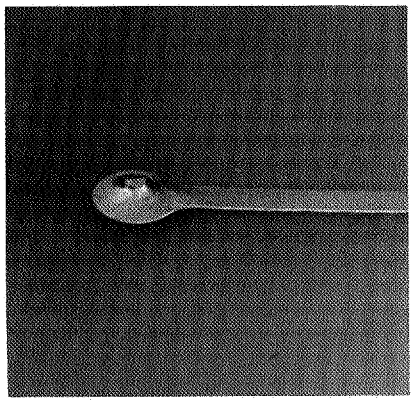


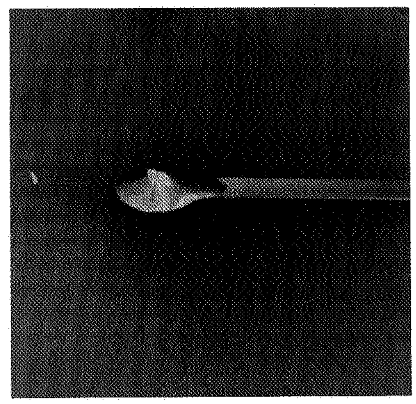


PWB LAPPED TERMINATION
Ribbon Lead From Same Side of Board to Rectangular Pad

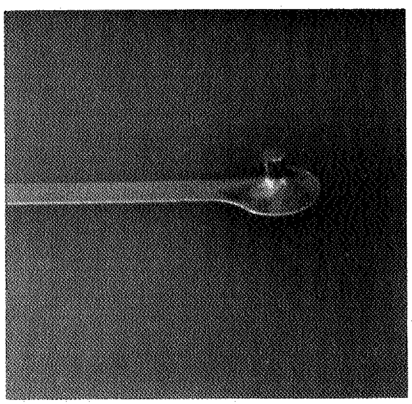
Minimum

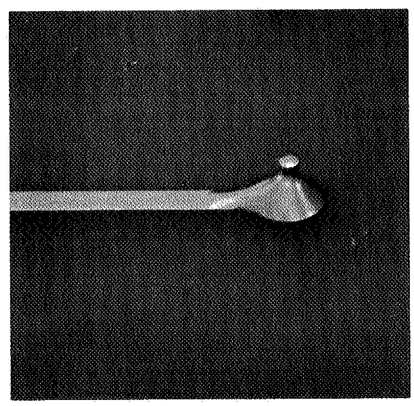
Maximum



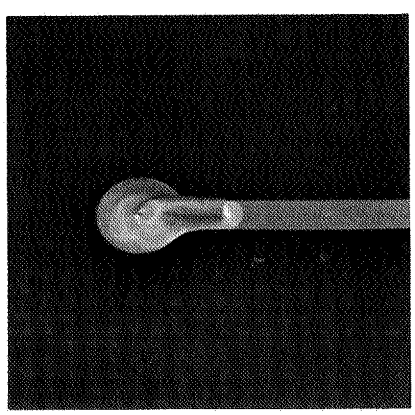


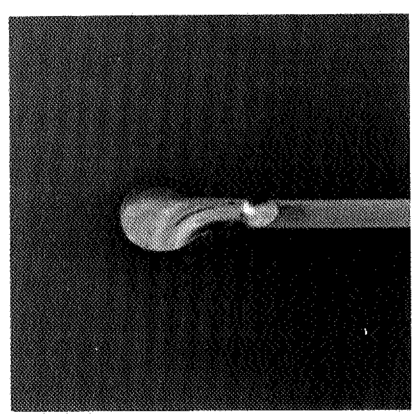
PWB STUD TERMINATION
Lead Protrusion 0.030 inches Above Pad





PWB STUD TERMINATION
Lead Protrusion 0.090 inches Above Pad

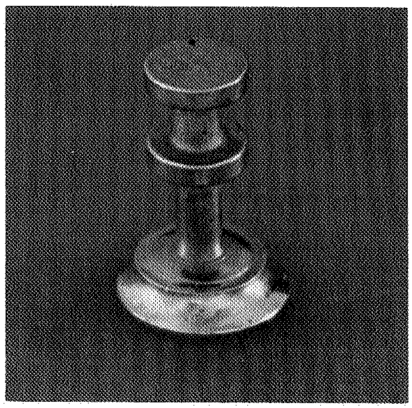


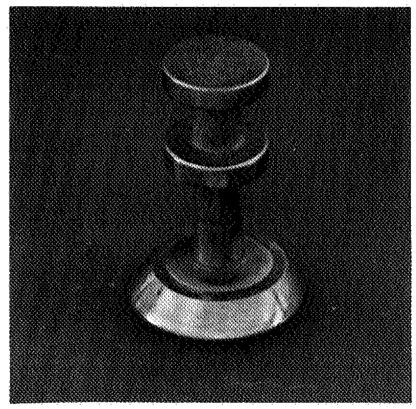


PWB CLINCHED TERMINATION
Round Lead to Circular Pad

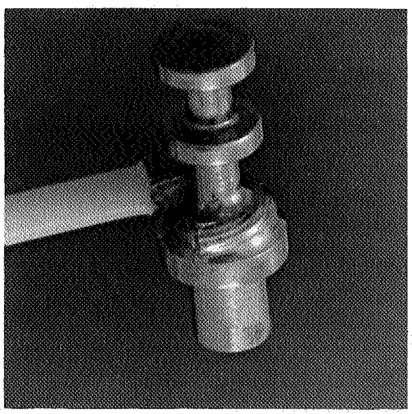
Minimum

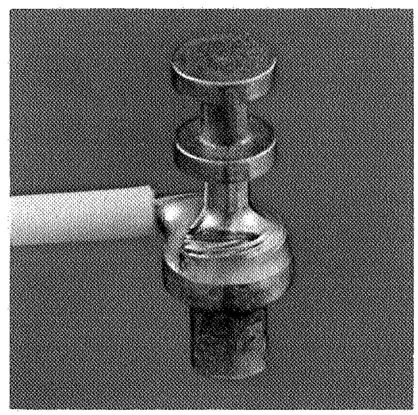
Maximum



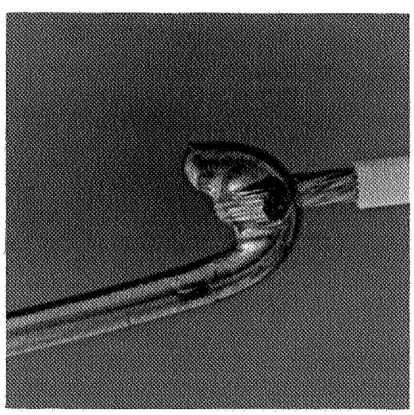


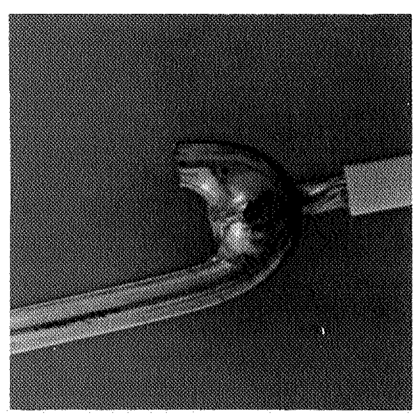
PWB TERMINAL MOUNTING
Soldering of Swaged Turret Terminal to Pad





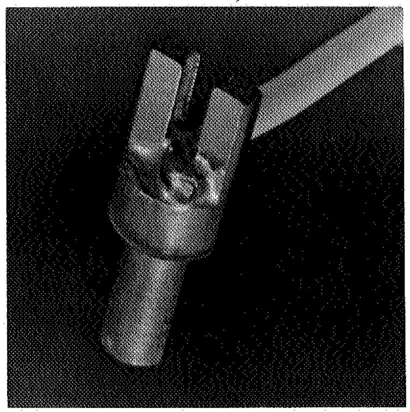
TURRET TERMINAL TERMINATION
Single Wire

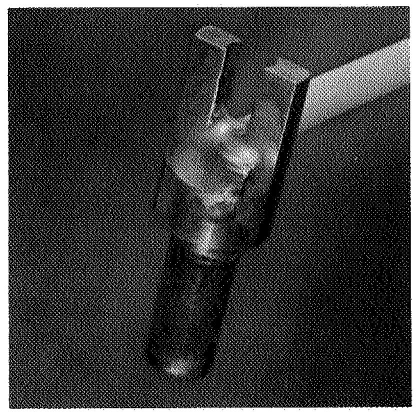




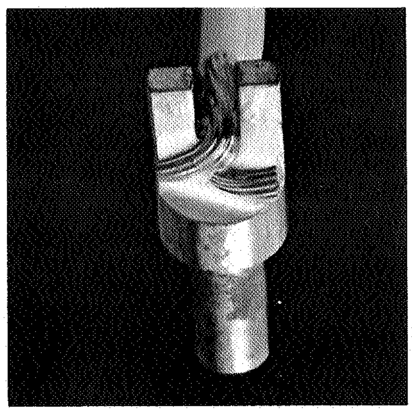
HOOK TERMINAL TERMINATION
Single Wire

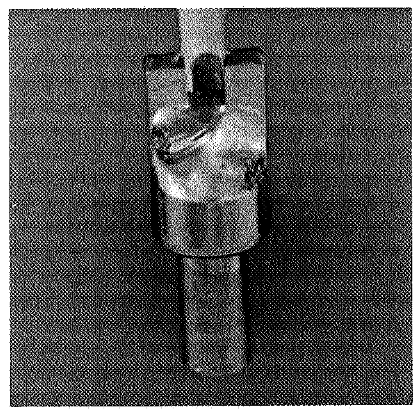
Minimum | Maximum



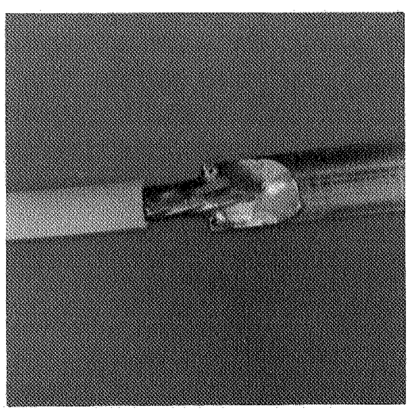


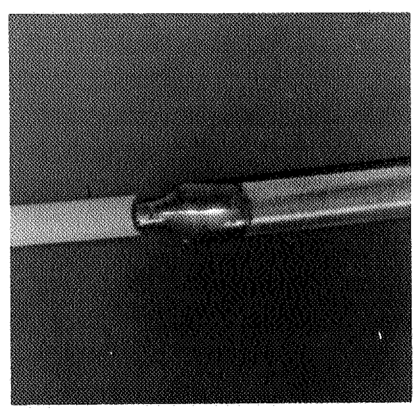
BIFURCATED TERMINAL TERMINATION
Single Wire





BIFURCATED TERMINAL TERMINATION
Two Wires





CUP TERMINAL TERMINATION
Connector Pin Type

APPENDIX C

SOLDER INTERCONNECT PROBLEMS ON PRINTED WIRING BOARDS

Reliable soldered joints require proper design. Particular attention must be given to stress relief, solder reinforcement when stress relief is not possible, material selection, and inspectability. This appendix describes in summary form some design problems and provides guidance for their solution. It also presents a degree of rationale for some of the requirements listed in this publication and specifically for Chapter 5, par. 3A500, Parts Mounting.

The most frequent problem encountered in maintaining a reliable soldered connection is the solder cracking phenomenon. This condition often occurs on perfectly soldered interconnections which pass all inspection criteria and initially function normally. Solder cracking and failure may occur within weeks or even years after installation and operation in the intended use.

Solder-copper separation is another problem that has caused failures on NASA hardware. It has a failure mechanism entirely different from solder cracking. Both failure mechanisms are evasive and time-temperature dependent. This discussion will deal with problems caused by thermal gradients and cycling. When solder fatigue or creep is present, a solder connection will ultimately crack with a small load that is only a fraction of that required to reach its nominal ultimate strength.

SOLDER CRACKING PROBLEMS

When an interconnecting part or lead with two or more constraint points is sufficiently stressed by expansion or contraction of the mounting media between these points, a fracture will occur at the weakest point in the connecting lattice. The weakest point in a vast majority of such failures encountered is the solder. The mounting media is generally a printed wiring board (PWB) and a thick fillet of conformal coating or a staking compound which bonds the electronic part (case) to the PWB, creating a mismatch of thermal expansion coefficients. The conductive metallic material, with a relatively low expansion coefficient, tends to restrict the PWB or conformal coating, an organic material with high expansion coefficient. The inevitable results are cracked solder connections.

Solder failures experienced under the conditions discussed above are the result of either the solder fatigue or the solder creep mechanism. Solder fatigue occurs during thermal cycling which "works" the joint through expansion/contraction of the constricted media material. The stressed conductor transmits the load to the solder joint which eventually cracks. Solder creep is the result of a constant low level load applied to the conductor and terminating with a solder connection. The solder atom lattice rearranges to accept the load until it is stressed beyond the solder yield strength. Cracking then results. Solder creep is a function of stress (load applied) and time. Solder fatigue is a function of time and intermittent stress usually caused by temperature variations.

Most solder failures are the result of a combination of both fatigue and creep. The temperature source may be environmental conditions and/or operational exotherm. More extreme temperatures accelerate the failure.

Figures 1 through 10 illustrate mounting configurations that induce stress and briefly identifies the cracking mechanism. Photographs are included to show the results of some of the parts mounting methods. Figures 1 through 4 depict the introduction of stress during fabrication of the interconnections. One common case of this condition occurs when the soldering iron, heated to approximately 340°C (644°F), heats and flows the solder on the conductive circuit pad. The PWB laminate expands (primarily in thickness) during formation and solidification of the solder joint. Upon cooling, the board laminate shrinks to its original dimension creating a tensile force that stresses the joint. Such fabrication stresses are known to have progressed to a solder crack within twelve hours. The mean-time-to-failure or cracking is dependent on the length of time the soldering iron remains in contact with the conductive surface and the thickness of the nonmetallic media (PWB). Longer dwell time with the soldering iron and thinner PWB's will intensify the stresses and accelerate cracking. Figures 5 through 10 show the results of varying thermal environments through thermal cycling and functional operations.

Other factors not illustrated, that favor solder cracking are:

1. **Large or stiff part lead material.** These materials resist flexing or bending, transferring the stress to the solder connection and the electronic part (piston action).
2. **Excessively large PWB holes for through-hole connections.** Soldering the lead to the solder pad over a large hole results in a thin solder bridge over the hole. In the absence of an off-pad design or a plated-thru-hole, this configuration is susceptible to cracking around the periphery of the hole (the weakest link in the interconnection).
3. **Standoff spacers or transipads under electronic parts when conformally coated.** Spacers or transipads are often made of material with a high coefficient of thermal expansion, e.g., nylon, etc. When bonded to the PWB and electronic part, a large thermal expansion mismatch is effected, and stresses are generated on the solder connection and part.

Methods found to relieve the solder cracking problems are:

1. Provide proper stress relief by changing the electronic part mounting configuration. (See Chapter 5.)
2. Use an organic (nonmetallic) material with coefficient-of-expansion properties that match those of the part-interconnect material.
3. Reinforce the soldered connection to withstand stresses applied.

TEMPERATURE TEST

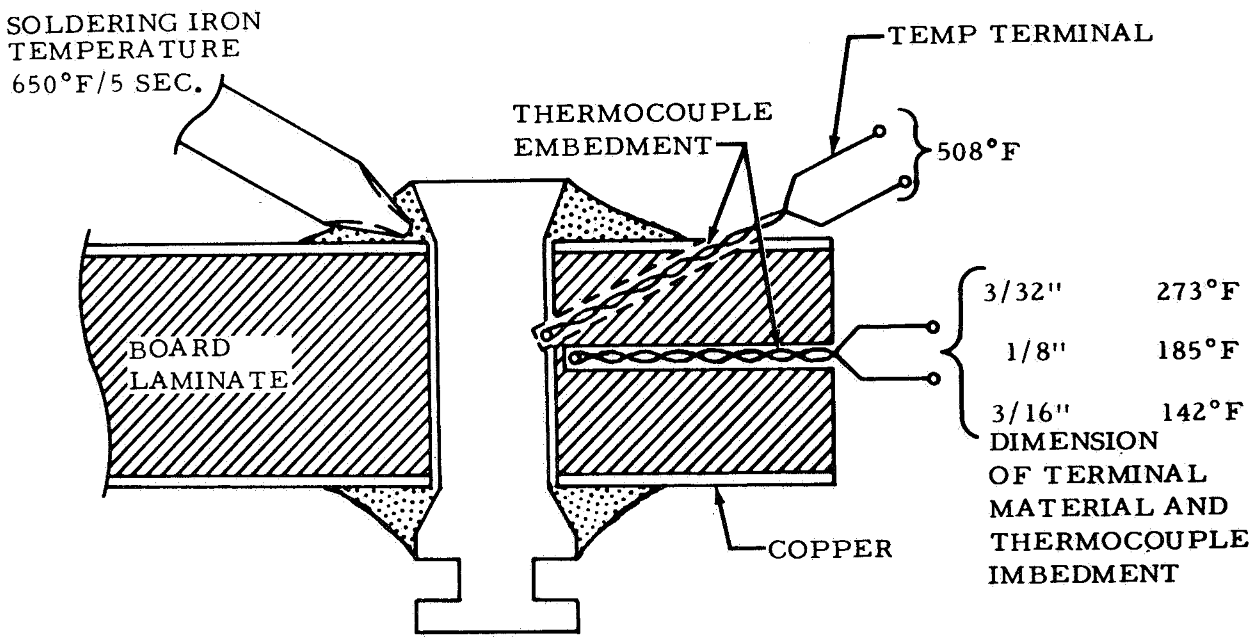
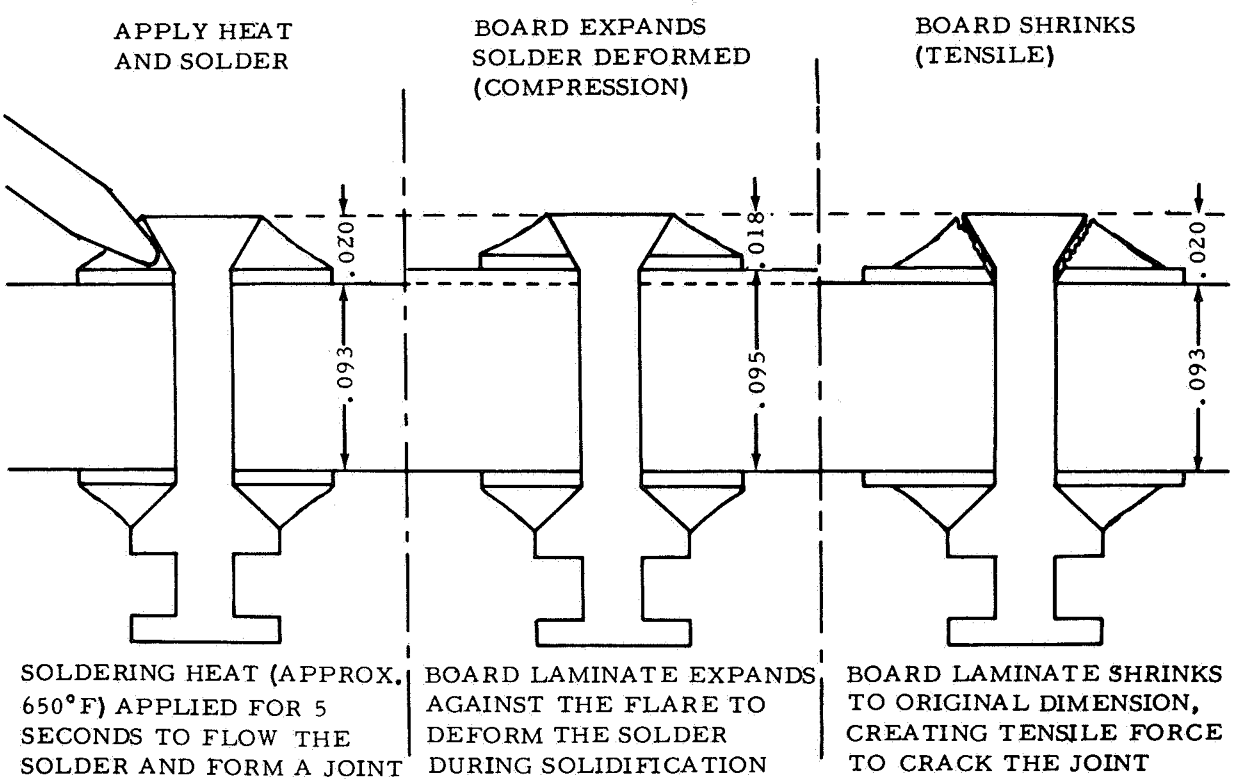


FIGURE 1

THERMAL CONDUCTIVITY/GRADIENT DURING SOLDERING OPERATION



(NOTE: This design should have a plated-through hole.)

FIGURE 2

DOUBLE-SIDED BOARD WITH INTERCONNECTING TERMINAL

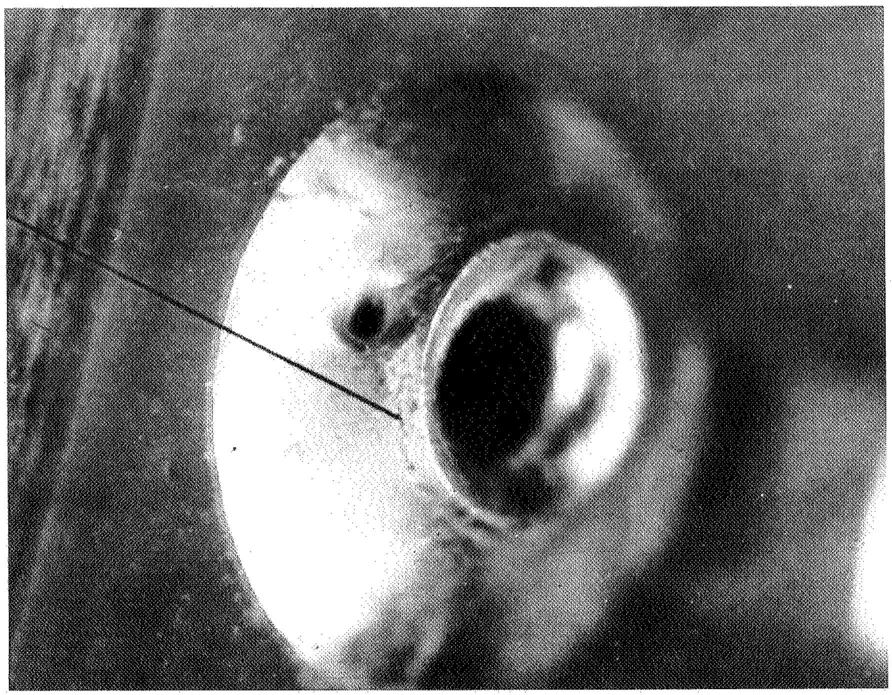
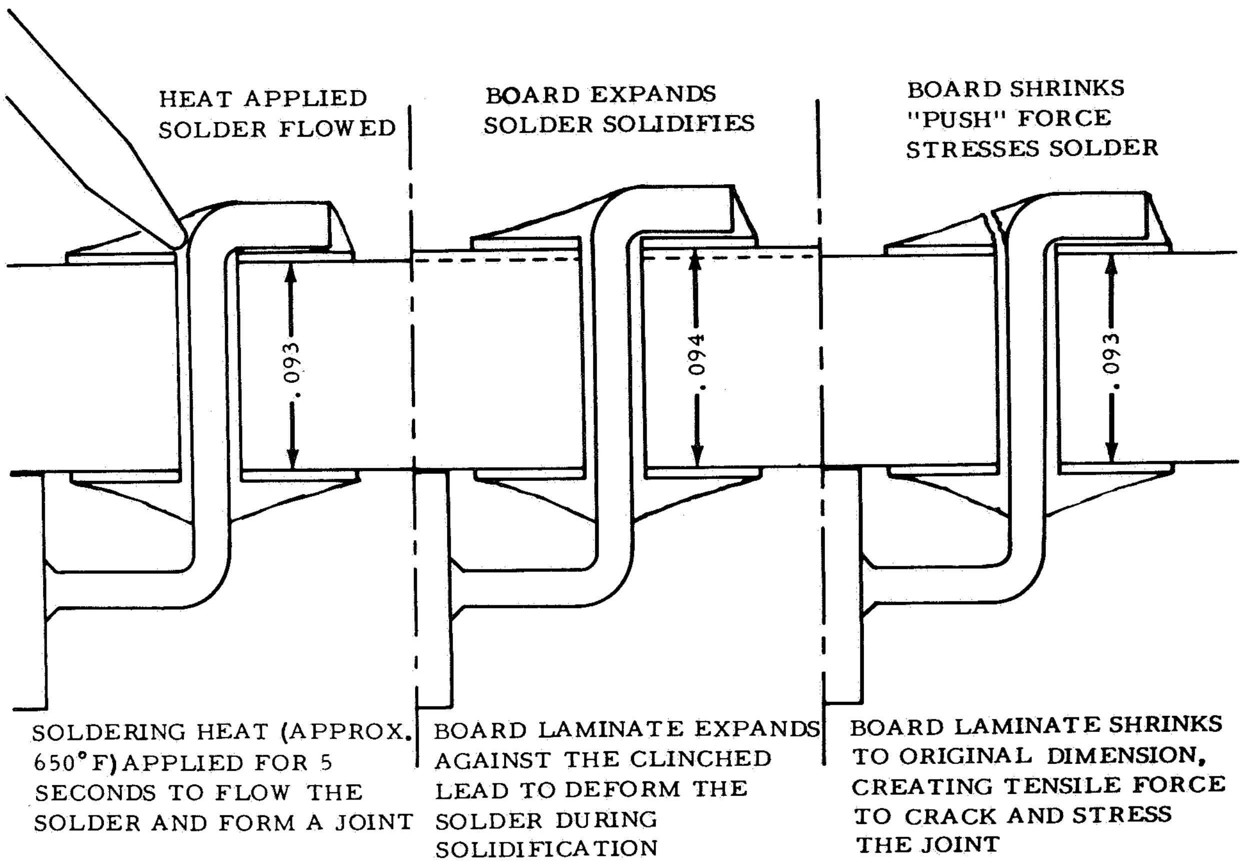


FIGURE 3

A CRACKED SOLDER CONNECTION AROUND A SWAGED TERMINAL INTERCONNECTION

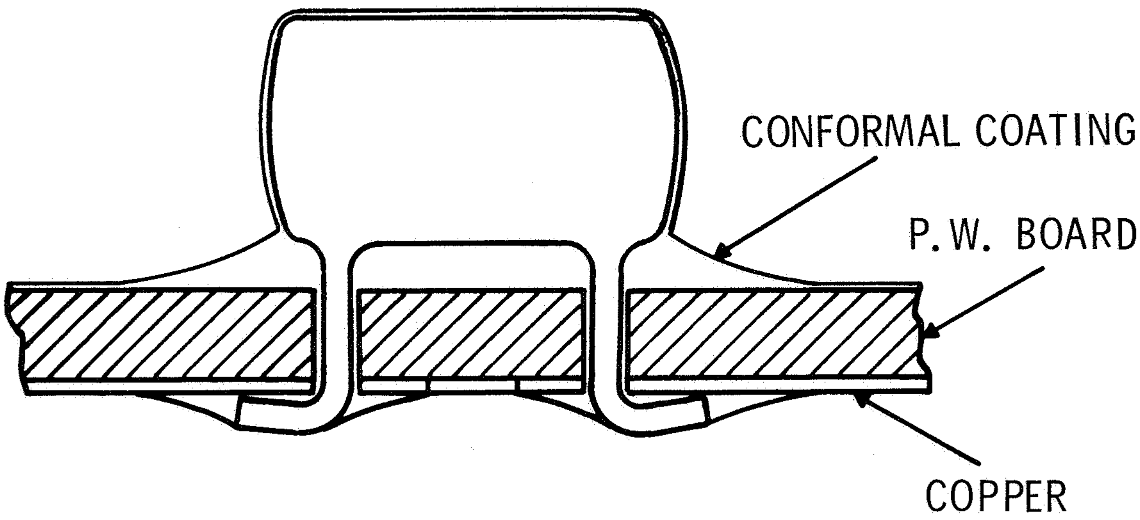
This crack began during 24 hour storage at 75°F and progressively enlarged during thermal cycling at temperature extremes of −65°F to +140°F. (NOTE: This joint design is used only for compelling design reasons.)



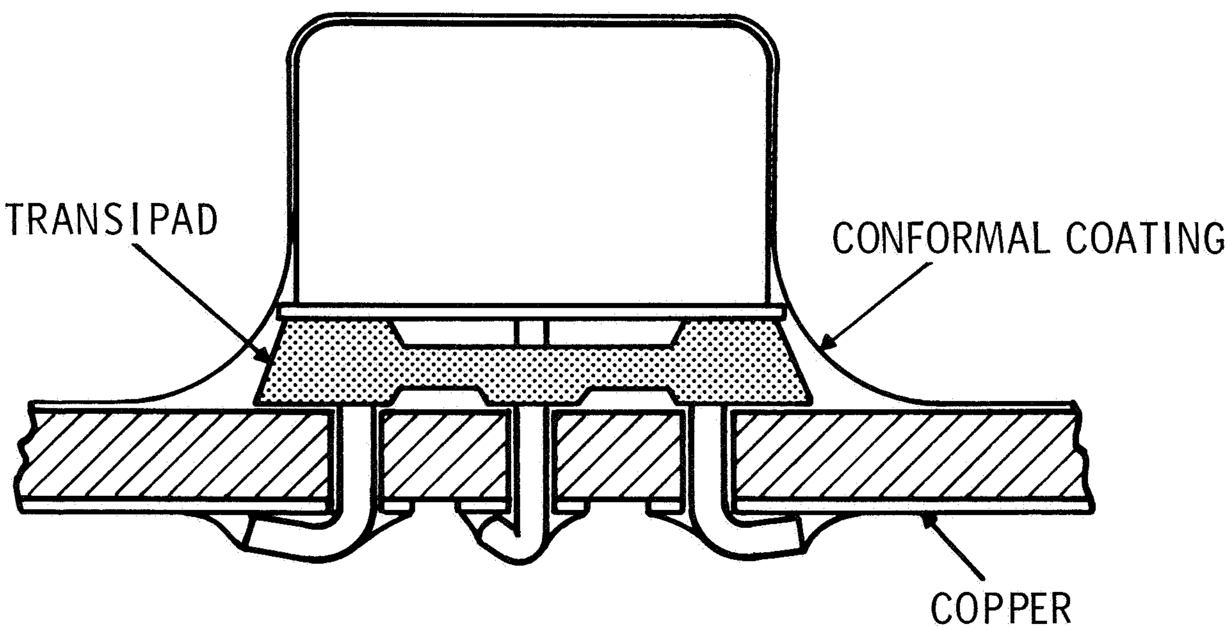
(NOTE: This joint should have a plated-through hole.)

FIGURE 4

DOUBLE-SIDED BOARD WITH INTERCONNECTING PART LEAD



KIDNEY CAPACITOR



TO-5 TRANSISTOR HOUSING

FIGURE 5

A HEAVY CONFORMAL COATING ON A TO-5 TRANSISTOR AND KIDNEY CAPACITOR

Cracking occurs due to the high coefficient of expansion of the conformal coating. When the conformal coating is applied as a liquid, it is placed in an oven to cure (generally at 140°F). Upon curing (hardening), it is removed from the oven to ambient temperatures. As the assembly cools, the conformal coating shrinks and, being bonded to the part body and the PW board, places a load (stress) on the soldered connection. Subsequent temperature cycles increase the load and accelerate solder cracking.

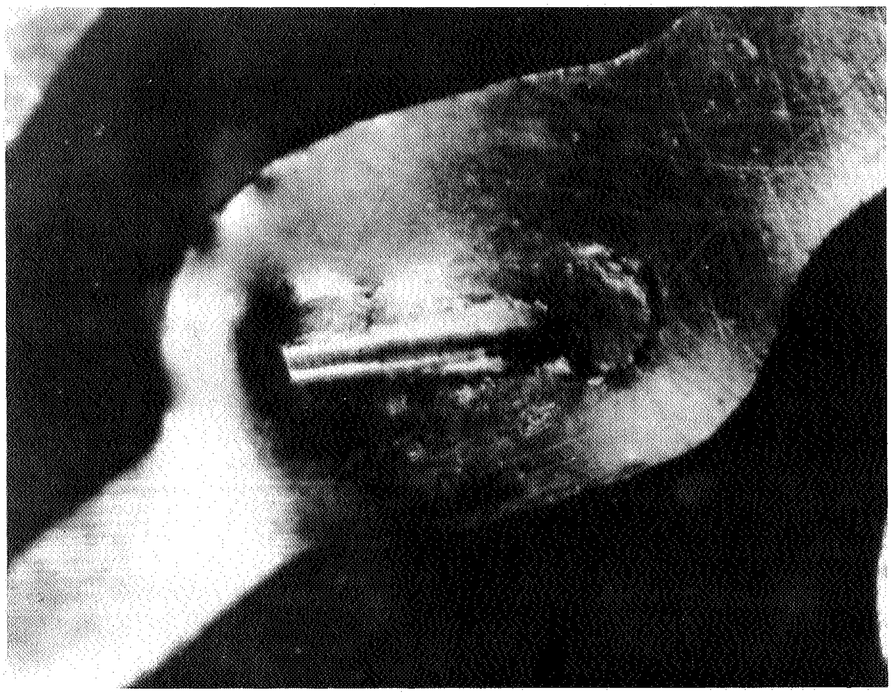


FIGURE 6

CRACKED SOLDER CONNECTION UNDER A CONFORMALLY COATED TO-5 TRANSISTOR HOUSING

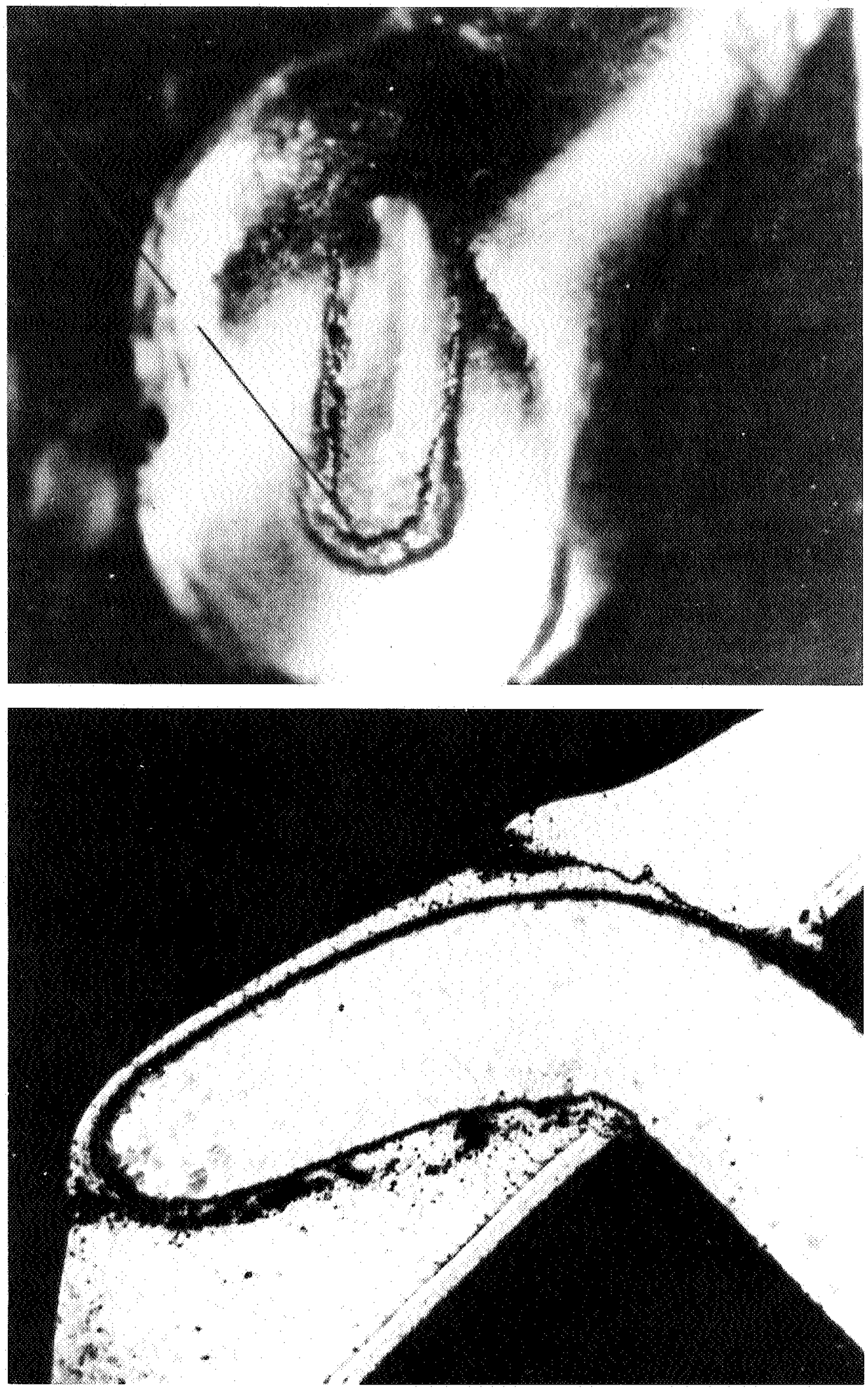


FIGURE 7

CRACKED SOLDER CONNECTION UNDER A CONFORMALLY COATED KIDNEY CAPACITOR

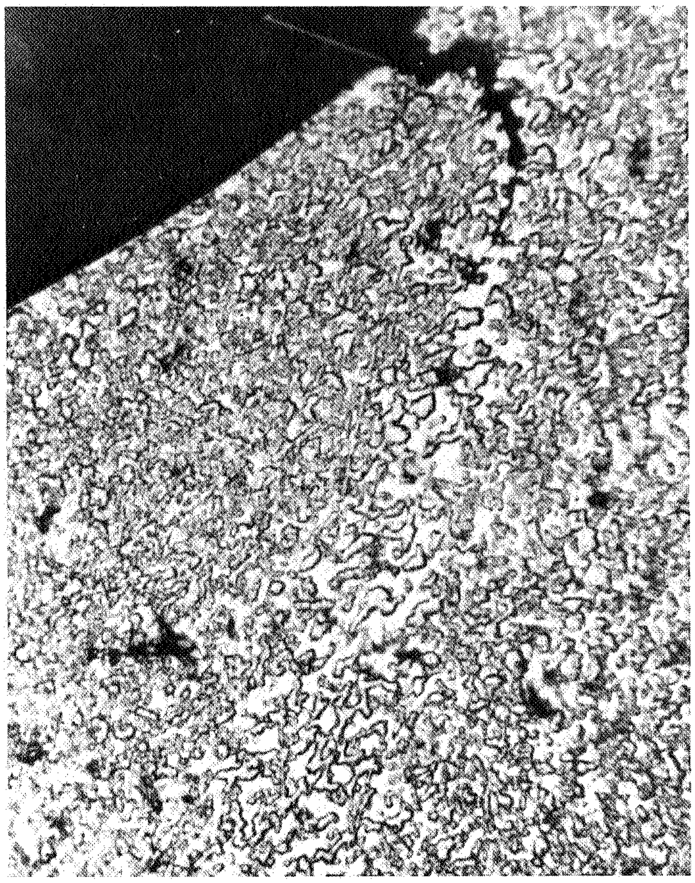


FIGURE 8
METALLOGRAPHIC EXAMPLE OF SOLDER CRACK AND STRESSED AREA

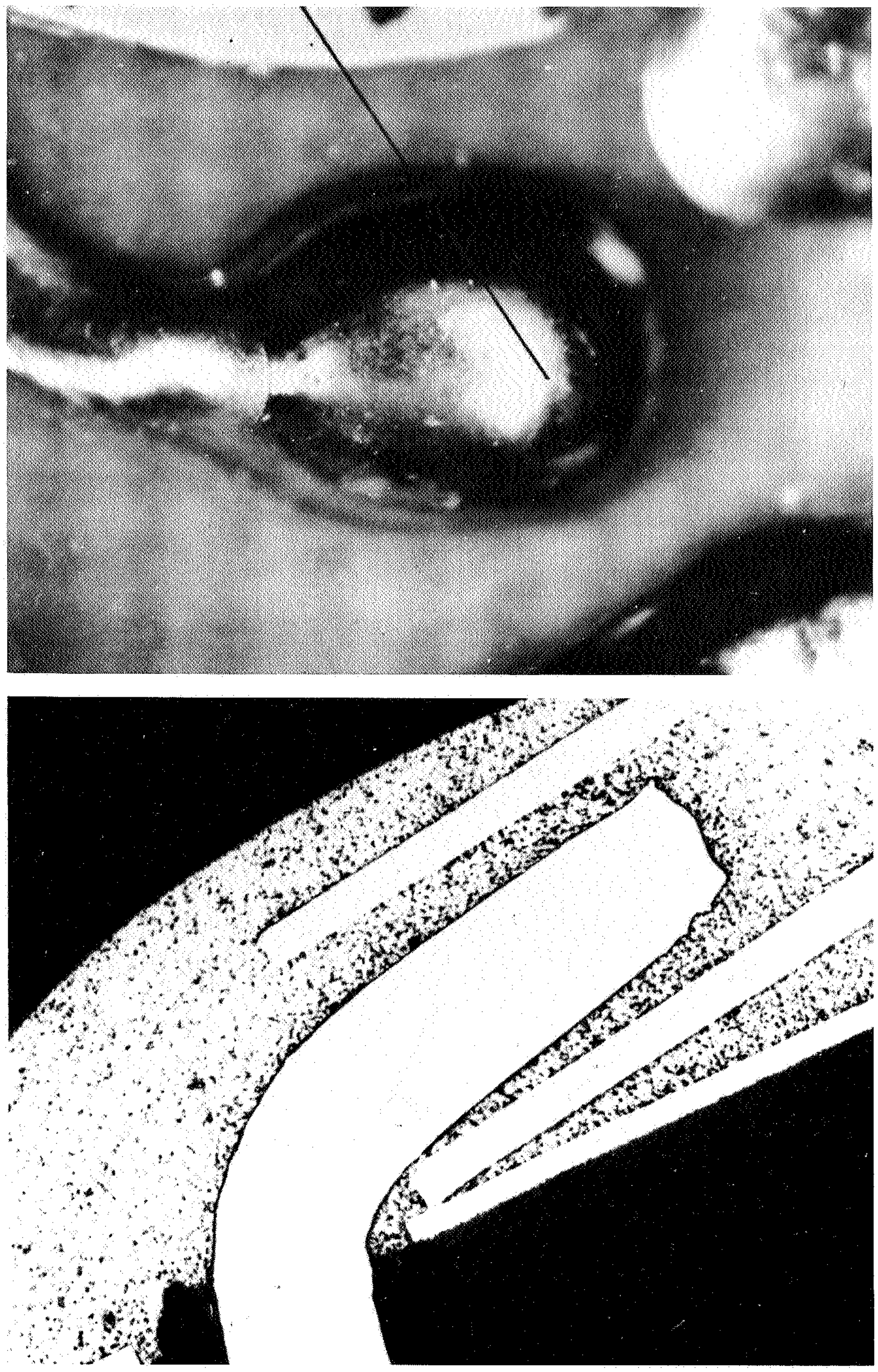


FIGURE 9

A PHOTOGRAPHIC AND METALLOGRAPHIC SECTION OF SOLDER REINFORCEMENT

A repair method only! A small tin coated copper tubelet is slipped over the lead of a heavily conformal coated transistor and soldered. This effectively distributes the load and cyclic stress effects of the coating expansion/contraction throughout the greater mass of solder and reduces solder cracking.

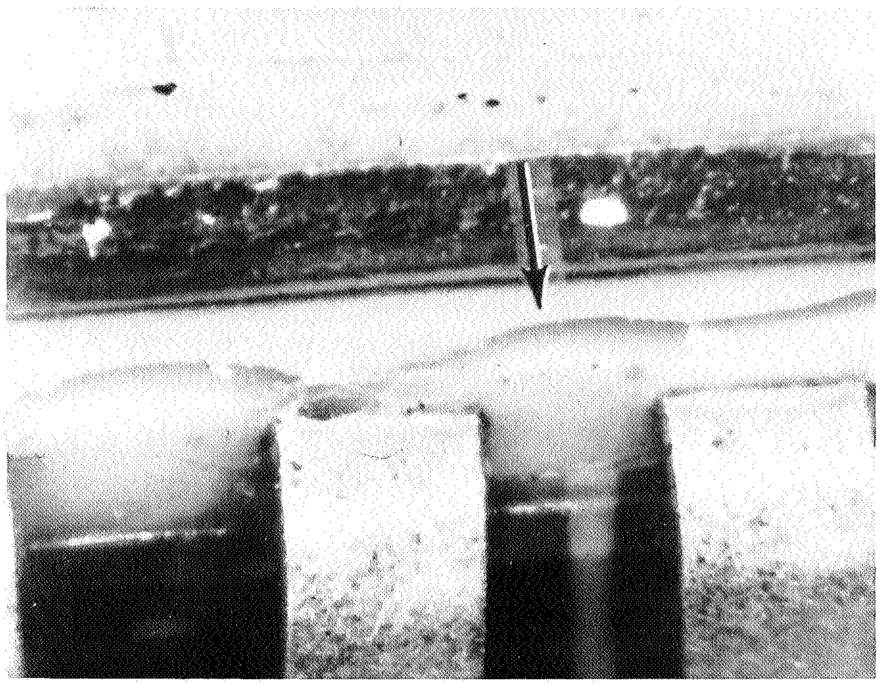


FIGURE 10

A CRACKED DUAL INLINE PACKAGE (DIP), CONFORMALLY COATED

This is an example of the "weakest point" being the glass sandwiched in a DIP. A thick conformal coating formed a fillet from the DIP body to the PWB. A load (stress) was placed on the solder connection and DIP. The DIP cracked, relieving the stress, and the solder connection remained intact.

SOLDER-CIRCUITRY SEPARATION PROBLEMS

Solder-circuitry separation problems differ from the solder cracking problem in that the solder cracking due to external stresses, occurs within the solder joint while the solder separation problem occurs at the interface of the solder and circuitry.

A detailed investigation (including failure analyses, metallographic examinations, chemical analyses, and a technical survey) has been conducted to isolate, define, and solve these solder-circuitry separation problems. Boards that exhibited solder-circuitry separation were double-sided circuitry plated with copper that contained brightener additives and was overplated with acid cyanide gold that contained cobalt. The circuit sides of the boards were wave soldered, and the component sides were hand soldered. Both sides, including the plated-through-holes, exhibited solder separation. A metallographic section is shown in Figure 11. Figure 12 is a photomicrograph after bond strength testing.

Research into gold plating solutions revealed the existence of a polymer that is codeposited with acid cyanide gold plating. Laboratory tests confirmed that this polymer could be isolated by a microchemical process. Elevated temperatures will, in time, concentrate the codeposited polymer at the solder-circuitry interface as a transparent film, reducing the interface bond strength to practically zero. (See Figure 13.) A similar failure mechanism is produced by brightener additives in copper plating solutions.

It was concluded that the solder-circuitry separation, caused by either soldering to acid cyanide gold or copper plating with organic additives, is not an immediate occurrence following the solder operation. It is a function of time and elevated temperatures which produces a progressive weakening of the bond at the solder-circuitry interface and ultimately an electrical failure.

It is recommended that copper plating solutions containing brighteners and other organic additives, and cyanide gold plating solutions be avoided in PWB fabrication processes. When gold plating is necessary it is recommended that a noncyanide gold be specified and that it be removed prior to soldering.

For additional information, refer to NASA TMX-2290, "Solder-Circuitry Separation Problems Associated with Plated Printed Circuit Boards," dated May 1971. (Available for purchase from the National Technical Information Service, Springfield, Virginia, 22151, price $3.75.)

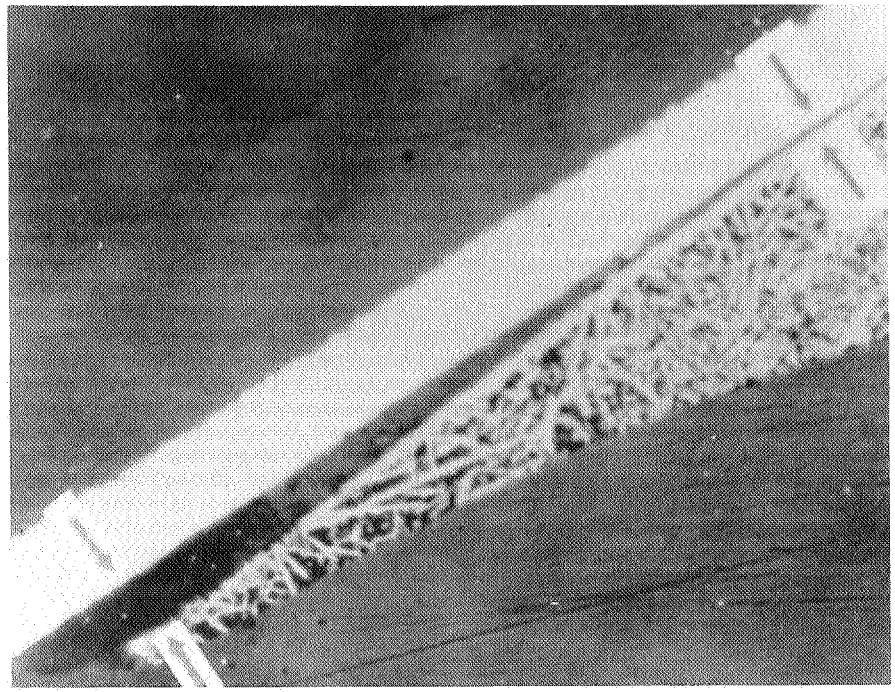


FIGURE 11

METALLOGRAPHIC SECTION OF SOLDER-COPPER SEPARATION

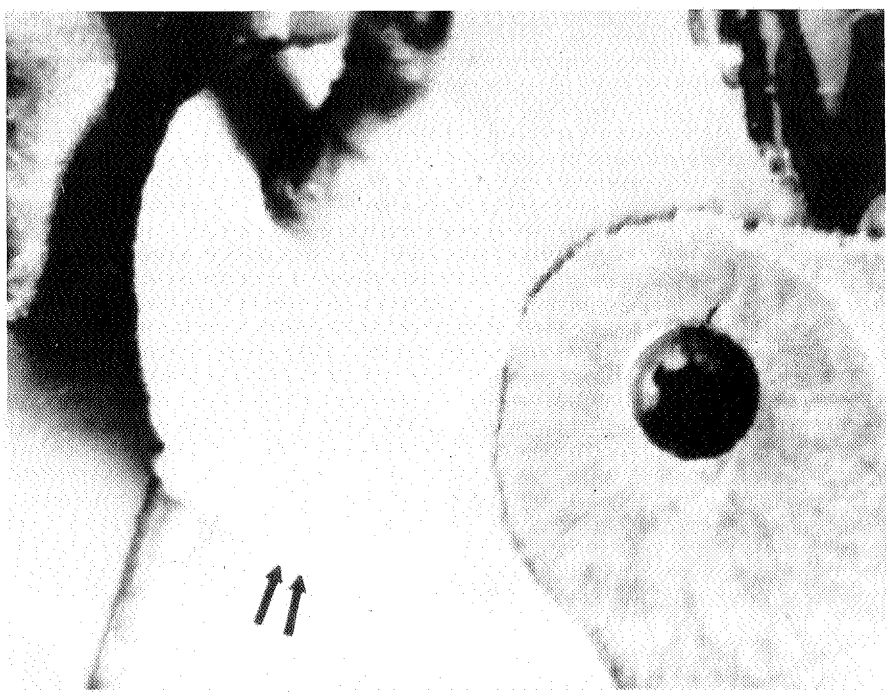


FIGURE 12

SOLDER-COPPER SEPARATION AFTER BOND STRENGTH TESTING

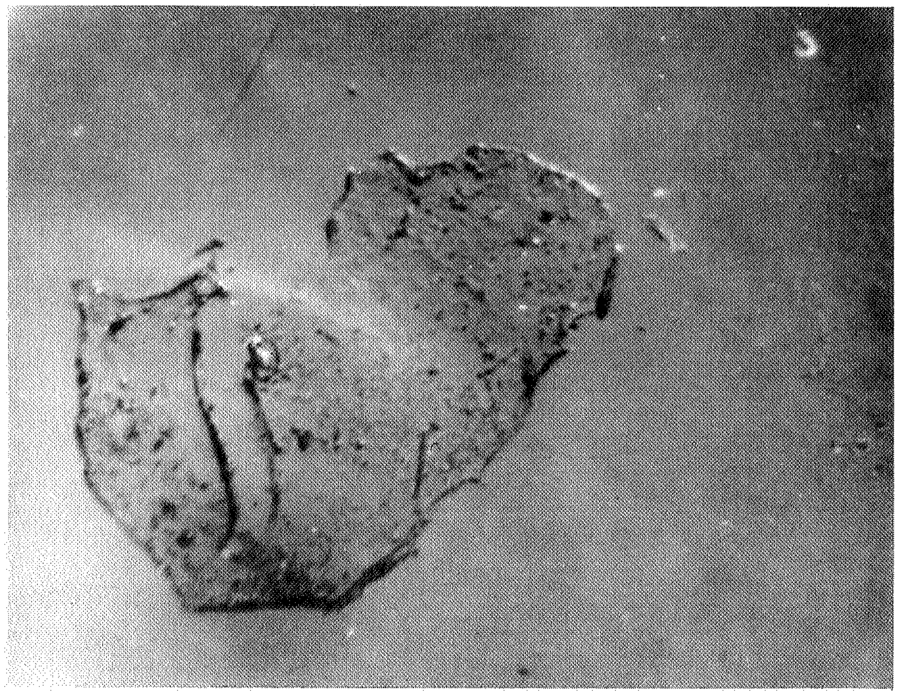


FIGURE 13
A TRANSPARENT POLYMER CODEPOSITED WITH ACID CYANIDE GOLD PLATING